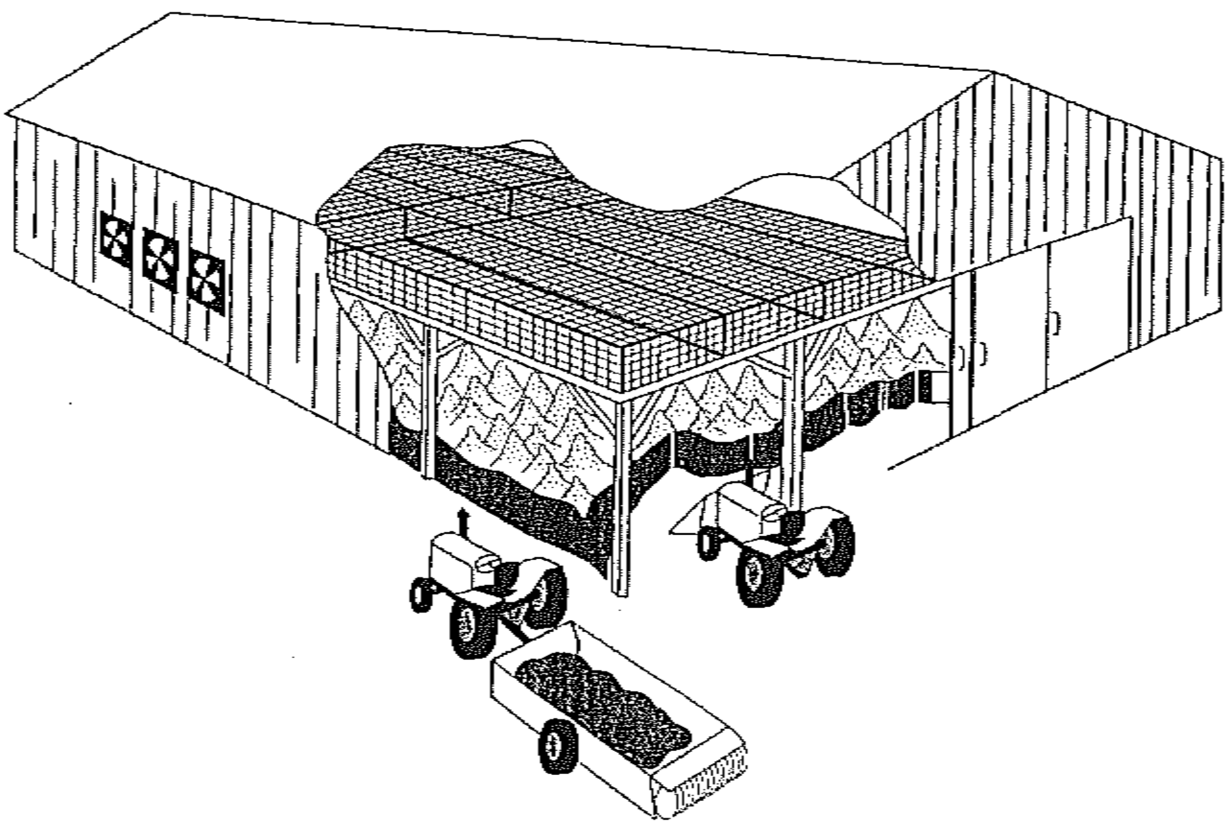
NRAES-132

Poultry Waste Management Handbook



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Cooperative Extension

NRAES-132

Poultry Waste Management Handbook

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Preliminary Considerations

One of the most important considerations for a poultry operation is waste management. Problems with storing, handling, managing, and utilizing the by-products of production have come to the forefront in planning, establishing, and operating poultry farms. In addition, producers have become sensitive to the potential for nuisance litigation should their farms generate odors, insects and vermin, runoff, or leachate that offends neighbors and passersby or endangers the environment.

Many different systems can be used successfully for storing and managing poultry wastes (see figure 1a, page 2). The character of the waste involved, the level of moisture in the waste, the soil type, and other site conditions are important factors in determining the suitability of any particular waste management system. Each grower must weigh the advantages and disadvantages of each method and decide which one best fits into the overall operation and best meets state and federal regulations. Regardless of the system chosen, success will largely depend upon proper operation and maintenance. It is up to the grower to establish a regular inspection and maintenance schedule to keep the waste management system functioning properly to protect the environment.

Storage of poultry wastes involves accumulating litter, manure, and wastewater in an environmentally sound manner until they can be applied to land, sold for composting, or used for other purposes. Dry litter or manure can be stored in solid form in stockpiles. Liquid manure can be stored in tanks or earthen basins, or it can be stored and treated in anaerobic lagoons or more advanced treatment systems. Manure storage facilities can provide environmental benefits by allowing wastes to be stored until they can be safely spread in a timely manner, incorporated into the soil, and used by a growing crop. See chapter 4, "Manure Storage," for more detailed information about storage options.

State environmental regulations address the location and size of storage facilities, minimum standards for seepage control from storage or treatment facilities, and operator management and training. The environmental acceptability of collecting large amounts of litter and manure in one place for an extended period depends on six factors:

- location of the storage site with respect to physical and chemical characteristics of the soil;
- subsurface geologic materials;
- design and construction of the storage site or facility, including measures to control runoff, seepage, and leachate;
- once the manure leaves the storage site or facility, proper land application and utilization of the manure at a rate compatible with nutrient uptake by crops;
- whether the location and design meet any applicable local, state, or federal regulations; and
- proper certification by state and local authorities, including training of operators and managers of waste handling facilities.

Groundwater protection should be a major consideration in siting poultry waste storage and treatment facilities. Factors to consider include topography, soils, and geology. Important soil characteristics include surface and subsoil texture, depth, and permeability. A very poor site has shallow soil, a high water table, or a very sandy/gravelly soil with excessive drainage and high permeability. Storage facilities in poor sites may require enhancement with compacted clay or synthetic liner materials.

Water supplies and wells should be located in an elevated area upslope of the poultry handling facilities, especially waste handling facilities. This will ensure that runoff will drain away from any wells or other water supplies in the vicinity. Most states set minimum separation distance requirements (typically 100 to 200 feet) between existing livestock facilities and new wells.

Minimum separation distance requirements also determine the placement of new well installations and the distance from existing wells to new potential sources of contamination. Well construction criteria might also exist. The law requires that existing wells meet only those separation requirements that were in effect at the time of well construction. However, every effort must be made to meet current regulations.

One way of reducing water pollution from poultry facilities and associated waste handling facilities is to reduce the amount of rainwater runoff entering the site. Suggestions for reducing potential water pollution from around poultry production complexes include:

- installation of waterways, small terraces, and roof gutters to direct water away from buildings, manure storage facilities, and dead bird disposal areas; and
- construction of an earthen ridge or diversion terrace upgrade and across the slope to prevent runoff from entering the production complex and waste storage facilities.

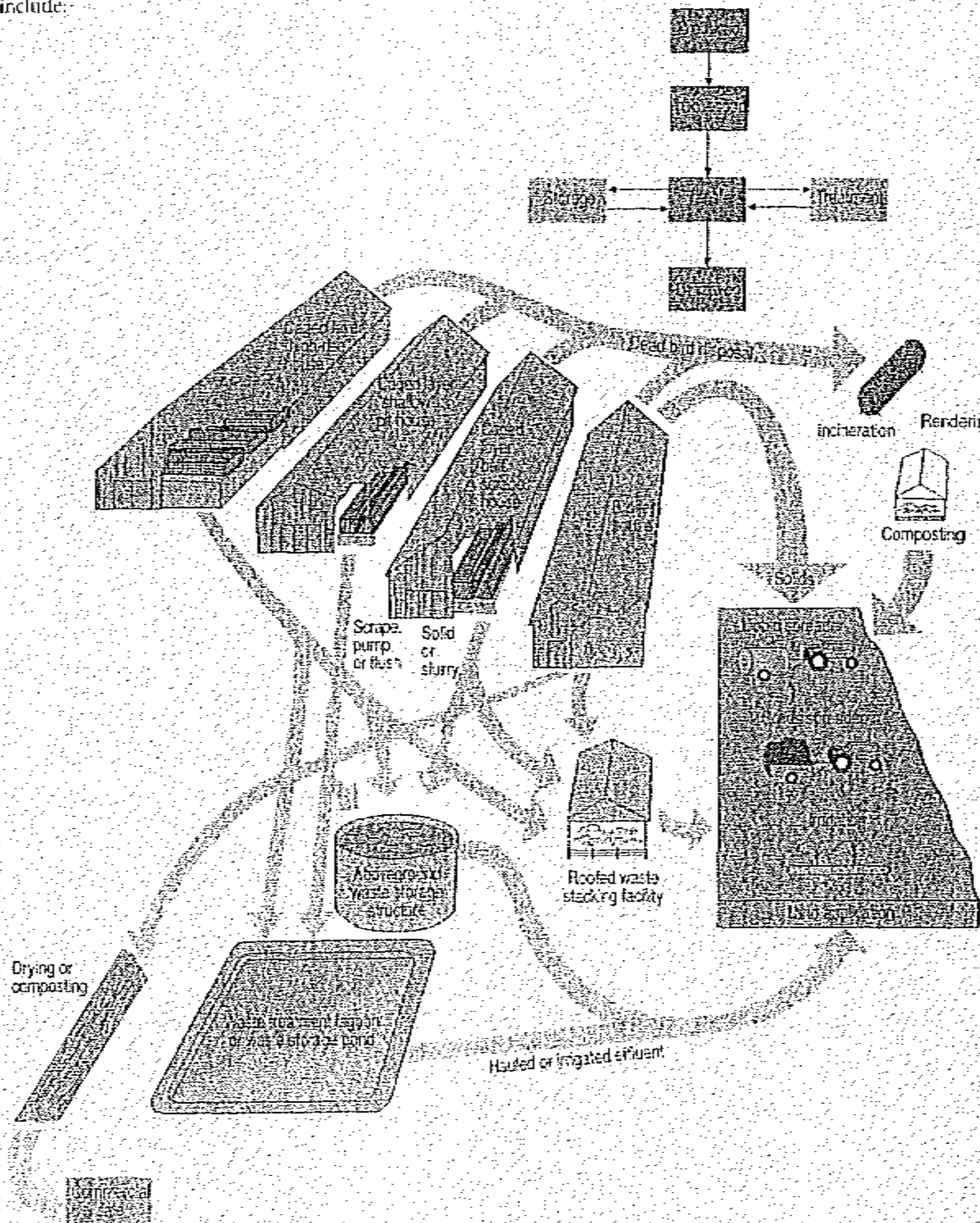


Figure 1a. Some waste handling options for poultry facilities

Source: Adapted from *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

CHAPTER 1

Manure Production and Characteristics

The quantity and characteristics of manure, wastewater, litter, and sludge must be known to plan, design, and operate manure collection, storage, pretreatment, and utilization systems for poultry enterprises. Manure properties are influenced by several factors:

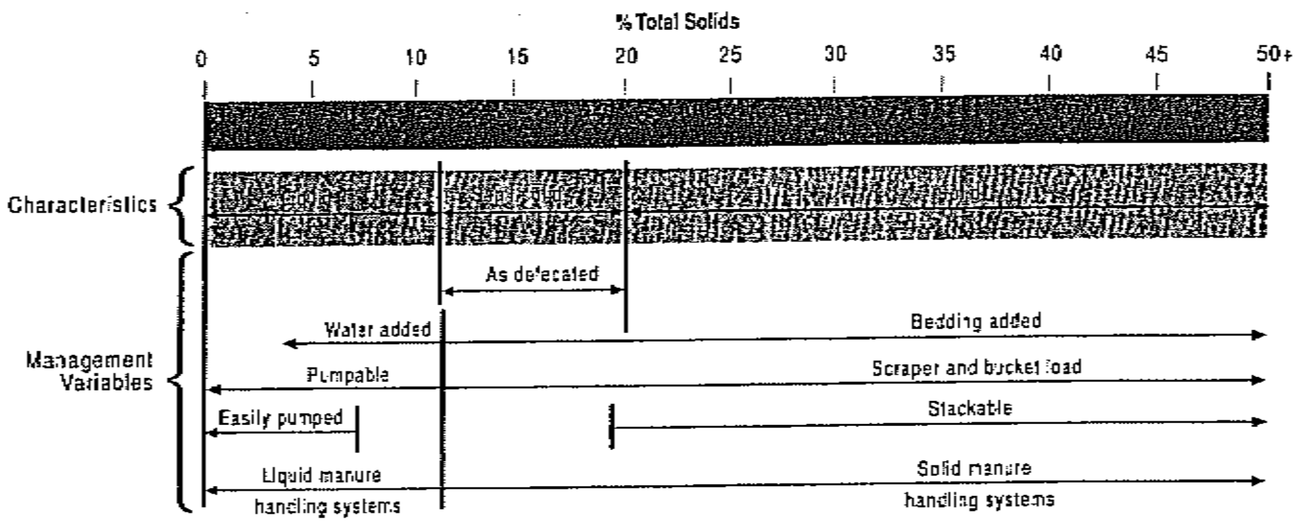
- bird species,
- bird age,
- diet and nutrition,
- bird productivity,
- management, and
- housing, ventilation, drinker systems, nutrition, and other environmental factors.

Manure Defined

The waste management system will collect bedding or litter, water, soil, grit, feathers, nonutilized dietary minerals, and other materials that must be handled as "manure." The term "manure" in this publication includes raw feces, urine, waste feed, spilled water, absorptive bedding used in poultry houses, and any other waste material that is part of the waste stream from production houses.

Materials with 20% or more total solids content can usually be handled as a solid (figure 1-1). These materials can be stacked, handled with a scraper and front-end loader, and spread with conventional manure spreaders. Most meat-type birds are raised on dry litter in production facilities, where the waste is handled in solid form and usually referred to as "litter."

Manure that is 12 to 20% solids is typically semi-solid and may need to be handled with box scrapers, bucket loaders, or tank spreaders equipped to contain liquids during transport. Some layer production facilities with alley (pit) scrapers or deep-pit storage may produce semi-solid or even liquid manure. This is generally due to improper maintenance or adjustment of water systems.



Approximate weight per cubic foot = liquid, 62.4 pounds; semi-solid, 60 pounds; thick solid, 50 pounds; light solid, 35 pounds. Ranges shown are only for manure mixed with organic bedding (i.e., bedding capable of absorbing large amounts of liquid).

Figure 1-1. Physical characteristics and handling requirements of manure

Source: Adapted from *Liquid Manure Application Systems Design Manual*, NRAES–89

Liquid slurries (4 to 12% total solids) will not stack. Special solids-handling pumps, liquid manure spreaders, or slurry irrigation systems are needed for these materials. Layer production facilities with holding tanks, settling basins, or earthen storage basins typically yield a liquid slurry. Also, sludge from the bottom of an anaerobic lagoon will fall into the slurry category. In this publication, semi-solid and liquid wastes will be called "manure."

When wastewater has less than 4% total solids content, its handling characteristics will be similar to those of water. However, feathers and other trash from poultry operations may necessitate special screening and/or pumping equipment. If these solid materials can be settled or otherwise removed from the wastewater, the wastewater can be pumped or irrigated with some of the same equipment used to pump clean water. Layer facilities with flushed alleys produce a wastewater around 2% total solids, while anaerobic lagoon liquid has a solids content around 0.5%.

Table 1-1 lists estimated manure production, as excreted. Data in this table represent averages from a wide database of published and unpublished information on poultry manure. Total manure production is presented per 1,000-bird capacity per day based on the weighted average daily live weight of the bird during its production cycle. Since manure production is generally based on the live weight of the bird, manure amounts may be increased or decreased proportional to the bird live weight. Each farm may have slightly different manure production rates due to factors already mentioned. Table 1-2 lists commonly used manure characteristics, as excreted.

Moisture Considerations

Table 1-3 (page 6) lists manure and wastewater produced from various types of waste storage and treatment systems for commercial layer production facilities. Production amounts can be highly influenced by leaking waterers, rainfall surplus added to open storage pits and lagoons, and whether or not fresh water is used for flushing or cleaning manure collection alleys. Table 1-4 (page 7) lists manure and wastewater characteristics, as removed from storage systems.

Undercage paved collection alleys are usually mechanically scraped, with solid or semi-solid manure collected over a two-day period. Liquids may evaporate from these shallow alleys between scrapings.

High-rise, deep-pit facilities usually allow manure to "cone" on paved or unpaved earthen floors for a year or longer before removal. Some states may require paving to provide greater insurance against groundwater contamination. Others may allow compacted clay floors to be used. The volume and moisture content of this solid or semi-solid manure can be influenced by leaking waterers, high humidity, or extent of ventilation. Circulation fans to move air over the manure mass can assist in moisture evaporation, increasing the dryness of the manure. Similarly, design and management of the total building ventilation system can either aid in drying the manure or cause moisture to accumulate to problem levels. Moisture can also be absorbed into the manure from the earthen floor surface or wicked from the manure into the soil, depending on surrounding soil moisture conditions.

Manure tanks, pits, or earthen storage basins receive scraped manure, excess water spillage, and surface rainfall surplus for

Table 1-1. *Manure production, as excreted*

	Live weight (lbs)		Total manure production per 1,000 birds per day		
Bird type	Market	Average	(lbs)	(ft^3)	(gallons)
Commercial layer					
Hen	4.0	4.0	260	4.2	32
Pullet	3.0	1.5	97	1.6	12
Broiler	4.5	2.25	177	2.8	21
Roaster	8.0	4.0	315	4.9	37
Cornish	2.5	1.25	99	1.5	12
Breeder	7.0	7.0	552	8.7	65
Turkey					
Poult	5.0	2.5	113	1.8	13
Grower hen	16.0	10.0	452	7.1	53
Grower tom, light	22.0	13.0	588	9.3	69
Grower tom, heavy	30.0	17.0	769	12.1	91
Breeder	20.0	20.0	905	14.3	107
Duck	6.0	3.0	328	5.3	39

NOTE: Data in this table represent averages from a wide database of published and unpublished information on poultry manure. Total manure production is presented per 1,000-bird capacity per day based on the weighted average daily live weight of the bird during its production cycle. Since manure production is generally based on the live weight of the bird, manure amounts may be increased or decreased proportional to the bird live weight. Each farm may have slightly different production rates.

Table 1-2. Typical manure characteristics, as excreted

Manure characteristics	Commercial layer	Broiler	Turkey	Duck
Density (lbs/ft³)	62	64	63	62
TS [a] (%)	25	26	25	27
VS [b] (%)	19	19	19	16
COD [c] (ppm)	176,000	197,000	236,000	169,000
	(lbs/ton)			
TKN [d]	27	26	28	28
NH_3N	6.6	6.7	8.1	7.4
P_2O_5	21	16	24	23
K_2O	12	12	12	17
Ca	41	10	27	29
Mg	4.3	3.5	3.1	4.1
S	4.3	2.0	3.3	3.6
Na	3.6	3.5	2.8	3.5
Cl	20	18	18	20
Fe	2.0	1.9	3.2	2.8
Mn	0.16	0.20	0.10	0.17
B	0.05	0.06	0.06	0.06
Zn	0.14	0.084	0.62	0.48
Cu	0.02	0.02	0.03	0.03

Sources: ASAE; Department of Biological and Agricultural Engineering, North Carolina State University

NOTE: All values are on a wet basis (as excreted)

- [a] TS = total solids (100 – TS = moisture or water content)
- [b] VS = volatile solids; the portion of total solids driven off as volatile (combustible) gases
- [c] COD = chemical oxygen demand; a measure of the oxygen-consuming capacity of inorganic and organic matter present in water or waste
- [d] TKN = sum or organic and ammonia(um) nitrogen, as measured by the laboratory Kjeldahl procedure

storage until spreading. Tanks and pits that can be covered usually receive less water, have a higher solids and nutrient content, and result in less slurry volume to handle than open earthen storage basins. Such storages are usually designed for four to twelve months' accumulation, depending on the amount of storage needed for an acceptable nutrient management plan.

Grit is a poultry feed ration additive that aids digestion. When used excessively, grit will separate from manure. Dietary calcium can also separate from manure and reduce both the flow of manure to holding tanks and the capacity of holding tanks to store manure. This may present handling challenges for liquid storage and handling systems.

Anaerobic lagoons (those that provide treatment without oxygen) are designed for biological treatment. The relatively large surface areas of lagoons often collect more surplus rainfall than dry manure stacks or liquid manure storage tanks. As a result, relatively large liquid volumes with comparatively dilute nutrient contents result from lagoon treatment. Bottom sludges are usually handled with liquid slurry equipment and are usually removed infrequently. Some nutrients such as calcium, phosphorus, zinc, and copper may be concentrated in lagoon sludges.

Aerobic treatment lagoons have not been used extensively for poultry wastes due to the need to maintain an environment that will sustain dissolved oxygen. Because of the high strength of poultry wastes, impractically large and shallow aerobic lagoons are necessary to maintain such an environment. Otherwise, oxygen must be incorporated into the lagoon using electrically powered aerators, which adds significant cost to the waste treatment process. There is interest in using aeration to reduce odor, provide better treatment, and produce a biomass that is easily settled from treatment effluent. The biomass can be removed and incorporated into compost or used in other ways as stabilized soil amendments.

Litter Considerations

Table 1-5 (page 8) lists litter characteristics, as removed from production houses. Table 1-6 (page 9) lists manure and litter production, as removed from various meat-type bird production facilities. Litter amounts are presented as tons per 1,000 birds. Bedding or litter materials (typically sawdust, wood shavings, peanut hulls, or rice hulls) are initially placed on floors to a depth of 2 inches or more (depending on the poultry integrator company) in production houses. Some companies require complete clean-out after every flock. Depending on disease status and management policies, companies may remove litter less frequently, on an average about once per year. In such cases, a thin layer of new litter may be added after each flock of birds, with wet and packed manure "cake" removed from around feeders and waterers between flocks. Some production facilities might go as long as 2 or 3 years before the litter base is replaced. These differences in management will influence the litter nutrient values, as will changing the amount or type of litter used. The values supplied in tables 1-5 and 1-6 are given as guides. Where litter will be used as fertilizer or for other purposes, it is wise to test the litter for nutrient content.

Moisture management in the production facilities can affect litter characteristics. As the litter becomes wetter (lower solids content), more ammonia will be released, and the nitrogen content of the litter will decrease. As litter dryness increases, increasingly dusty conditions will exist within the facility. A number of factors influence litter moisture. When fed in excess, certain dietary ingredients (especially salt) cause birds to consume and excrete large amounts of water, resulting in wet litter conditions. Some drugs stimulate excess

Table 1-3. Typical commercial layer waste production, as removed from storage

Bird type	Live weight (lbs) Market	Average	Total waste production (per 1,000 birds per day) (lbs)	(ft³)	(gallons)
			Undercage collection alley-scraped manure [a]		
Hen	4.0	4.0	155	2.5	19
Pullet	3.0	1.5	58	0.9	7
			High-rise, deep-pit stored manure [b]		
Hen	4.0	4.0	108	2.1	16
Pullet	3.0	1.5	41	0.8	6
			Liquid manure slurry [c]		
Hen	4.0	4.0	356	6.1	46
Pullet	3.0	1.5	134	2.3	17
			Anaerobic lagoon liquid [d]		
Hen	4.0	4.0	587	9.4	70
Pullet	3.0	1.5	220	3.5	26
			Anaerobic lagoon sludge [e]		
Hen	4.0	4.0	108	1.7	13
Pullet	3.0	1.5	41	0.65	5

Source: Department of Biological and Agricultural Engineering, North Carolina State University

NOTE: Production amounts can be highly influenced by leaking waterers, rainfall surplus added to open storage pits and lagoons, and whether or not fresh water is used for flushing or cleaning manure collection alleys.

[a] Manure scraped from paved alley and collected within two days

[b] Annual manure accumulation stored on unpaved surface

[c] Manure, excess water usage, storage surface rainfall surplus; does not include fresh water for flushing

[d] Manure, excess water usage, lagoon surface rainfall surplus; does not include fresh water for flushing

[e] No manure solids removal prior to lagoon treatment/storage

water consumption and excretion. Environmental conditions, such as wet and humid weather or very cold temperatures, can cause wet litter if the house heating and ventilation system is not able to eliminate moisture effectively. Waterers, foggers, and evaporative cooling pads, if not managed and maintained carefully, can contribute greatly to wet litter problems. Ideally, litter moisture should be maintained at 20 to 25%.

Around waterers and feeders, additional manure and moisture tend to form crusted or caked areas of litter that have different handling and nutrient characteristics than the other house litter. This manure cake represents about 30 to 35% of the total litter. The manure cake around waterers is usually wetter and has a lower nutrient content than the total litter. But the area around feeders is often drier and has a higher nutrient content due to feed spillage. The cake may be removed with crusting equipment after each flock of birds. (See chapter 7, "Application Equipment," for more information about crusting equipment.)

Table 1-7 (page 9) gives estimates of manure and litter volumes that have been removed from production facilities to an outside uncovered stockpile on an earthen surface for storage up to six months before field spreading. The litter mass removed from the stockpiles is, in most cases, only slightly less than that taken directly from the production facilities. Absorption of rainwater in the stockpiles is offset by a reduction in solids due to composting action. Covering the stockpile or storing the litter inside a roofed structure reduces losses and preserves a higher-quality litter. Covering the stockpile also reduces the potential for nutrient leaching or nutrient loss to the environment in runoff.

Nutrient Considerations

Table 1-8 (page 10) shows typical litter characteristics, as removed from open stockpiles. As can be seen from the table, phosphorus is conserved in open stockpiles and potassium levels are only slightly less than those of house litter. The nitrogen content, however, is about half that of broiler and turkey house litter due to the loss of ammonia caused by wetting and resulting biological activity. Again, storing litter in a dry structure will conserve nitrogen.

Table 1-9 (page 10) estimates typical nitrogen losses between excretion and land application on a mass basis. Bedding and water dilute manure, resulting in less nutrient value per pound. Substantial nitrogen can be lost to the atmosphere as ammonia. The least nitrogen losses are associated with slurry storage pits, dry-house whole litter, and roofed storages. Deep-pit manure stacking and open stockpiled litter have moderate to high nitrogen losses. Lagoons have the highest loss.

Phosphorus and potassium losses are usually negligible, except with lagoons. Much of the phosphorus in lagoons concentrates in and is recoverable with the bottom sludge. Moderate amounts of potassium may be lost from open uncovered stockpiles due to leaching.

Sampling and Testing

The values in tables 1-1 through 1-8 are estimates based on averages from large databases. Actual farm-specific manure production and characteristics may vary considerably from the averages. As-excreted values may vary up to 30% from the average due to bird productivity, age,

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Table 1-4. Typical commercial layer waste characteristics, as removed from storage

Manure characteristic	Undercage collection alley-scraped manure [a]	High-rise deep pit stored manure [b]	Liquid manure slurry [c]	Anaerobic lagoon liquid [d]	Anaerobic lagoon sludge [e]
Density (lbs/ft³)	62	51	58	62	62
TS [f] (%)	35	53	11	0.49	17
VS [g] (%)	25	32	7.4	0.22	7.3
COD [h] (ppm)	270,000	286,000	106,000	2,950	28,600
			(lbs/ton)		
TKN	28	34	57	6.6	21
NH_3N	14	12	37	5.6	6.5
P_2O_5	32	51	52	1.7	77
K_2O	20	26	33	10.3	9.8
Ca	41	76	33	1.1	47
Mg	5.5	5.7	4.0	0.34	12
S	7.1	4.8	4.0	0.61	7.1
Na	2.8	3.3	4.8	1.8	3.3
Cl	4.0	6.0	6.6	3.4	2.4
Fe	2.4	2.8	1.7	0.060	4.8
Mn	0.29	0.44	0.38	0.0069	1.6
B	0.022	0.036	0.030	0.0092	0.035
Zn	0.31	0.35	0.39	0.016	1.1
Cu	0.034	0.058	0.073	0.004	0.14

Source: Department of Biological and Agricultural Engineering, North Carolina State University

NOTE: All values are on a wet basis (as excreted)

- [a] Manure scraped from paved alley and collected within two days
- [b] Annual manure accumulation stored on unpaved surface
- [c] Manure, excess water usage, storage surface rainfall surplus; does not include fresh water for flushing
- [d] Manure, excess water usage, lagoon surface rainfall surplus; does not include fresh water for flushing
- [e] No manure solids removal prior to lagoon treatment/storage
- [f] TS = total solids (100 – TS = moisture or water content)
- [g] VS = volatile solids; the portion of total solids driven off as volatile (combustible) gases
- [h] COD = chemical oxygen demand; a measure of the oxygen-consuming capacity of inorganic and organic matter present in water or waste

or diet. Variances of 25% for dry-house litter to as much as 60% for open liquid manure or lagoon systems are common because of differences in management or environmental factors. For these reasons, where possible, samples of the actual farm manure, litter, or wastewater should be collected and analyzed by local laboratories or testing facilities to provide more accurate information for planning, design, and land application.

Laboratory analyses are only as accurate as the sampling method. Care must be taken to obtain a sample that is representative of the entire waste volume. If samples of whole litter are collected directly from a production facility, take about six subsamples of litter in proportion to expected variations throughout the facility. For example, if one-sixth of the floor area is cake, take one subsample from this area and five subsamples from the rest of the house. It is important to collect core samples that are taken from the litter surface down to the floor. Mix them together in a nonmetallic container and place about 2 to 3 pounds in a 1-gallon freezer bag and seal. From a stockpile, collect about six subsamples from at least 18 inches into the pile. Open stockpiles often have a wet surface layer; be sure that the sample taken is representative of the entire stack.

Subsamples of scraped, semi-solid layer manure should be collected either directly from the alley or from the manure spreader. Place 2 to 3 pounds of the subsamples in a nonmetallic container such as a plastic jar or bag. Be sure the container has expansion space for any gases that may be released while it is in transit to the testing laboratory.

Liquid manure slurries in storage tanks or basins must be well agitated before a representative sample can be collected. Once this mixing has occurred, collect about six subsamples from the storage tank, agitator pump, or manure spreader, and place them in a nonmetallic container. Mix the subsamples and add about ¾ pint to an expandable sample container, leaving about one-quarter of the container empty; otherwise, gases released from the manure may cause rupturing of and spillage from the container.

Lagoon liquid can be sampled directly from the lagoon by taking about six subsamples

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Table 1-5. Typical litter characteristics, as removed from production houses

Bird type	Density (lbs/ft³)	TS[a] (%)	VS[b] (%)	TKN[c]	NH_3-N	P_2O_5	K_2O	Ca	Mg	S	Na	Cl	Fe	Mn	B	Zn	Cu
				(lbs/ton)													
Broiler																	
Whole litter[d]	32	79	63	71	12	69	47	43	8.8	12	13	13	1.2	0.79	0.057	0.71	0.53
Manure cake[e]	34	60	47	46	12	53	36	34	7.0	9.2	10	—[f]	1.2	0.69	0.044	0.60	0.41
Roaster																	
Whole litter[d]	29	76	59	69	16	70	47	41	8.4	14	13	—[f]	1.6	0.76	0.047	0.68	0.49
Cornish																	
Whole litter[d]	30	68	53	59	12	57	59	41	22	—[f]	—[f]	—[f]	—[f]	1.1	—[f]	0.92	0.61
Manure cake[e]	34	54	42	62	17	39	39	30	14	—[f]	—[f]	—[f]	—[f]	0.67	—[f]	0.50	0.46
Breeder																	
Whole litter[d]	50	69	29	37	8.0	58	35	83	8.2	7.8	8.3	—[f]	1.2	0.69	0.034	0.62	0.23
Turkey poult																	
Whole litter[d]	23	80	62	40	9.6	43	27	26	5.1	6.1	4.7	1.8	2.0	0.53	0.038	0.46	0.39
Grower																	
Whole litter[d]	32	73	53	55	12	63	40	38	7.4	8.5	7.6	12	1.4	0.80	0.052	0.66	0.60
Manure cake[e]	35	55	44	45	20	47	30	26	5.4	6.3	5.5	—[f]	1.2	0.56	0.038	0.47	0.48
Breeder																	
Whole litter[d]	50	78	34	35	7.6	47	18	72	4.6	7.4	4.3	—[f]	1.0	0.43	0.031	0.50	0.40
Duck																	
Whole litter[d]	50	37	24	17	3.6	21	13	22	3.3	3.0	3.0	—[f]	1.3	0.37	0.021	0.32	0.04

Source: Department of Biological and Agricultural Engineering, North Carolina State University

NOTE: All values are on a wet (as is) basis

[a] TS = total solids (100 − TS = moisture or water content)

[b] VS = volatile solids; the portion of total solids driven off as volatile (combustible) gases

[c] TKN = sum of organic and ammonia(um) nitrogen as measured by the laboratory Kjeldahl procedure

[d] Annual manure and litter accumulation; typical litter base is sawdust, wood shavings, or peanut hulls

[e] Surface manure cake removed after each flock

[f] Data not available

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Table 1-6. Typical litter production, as removed from production houses

Bird type	Live weight (lbs)		Total litter production per 1,000 birds sold (tons)
	Market	Average	
Broiler			
Whole litter[a]	4.5	2.25	1.25
Manure cake[b]	4.5	2.25	0.4
Roaster			
Whole litter[a]	8.0	4.0	2.6
Cornish			
Whole litter[a]	2.5	1.25	0.625
Manure cake[b]	2.5	1.25	0.06
Breeder			
Whole litter[a]	7.0	7.0	24.0[c]
Turkey poult			
Whole litter[a]	5.0	2.5	1.0
Grower hen			
Whole litter[a]	16.0	10.0	8.0
Manure cake[b]	16.0	10.0	2.5
Grower tom, light			
Whole litter[a]	22.0	13.0	10.0
Manure cake[b]	22.0	13.0	3.3
Grower tom, heavy			
Whole litter[a]	30.0	17.0	14.0
Manure cake[b]	30.0	17.0	4.4
Breeder			
Whole litter[a]	20.0	20.0	50.0[c]
Duck			
Whole litter[a]	6.0	3.0	4.25

Sources: Department of Biological and Agricultural Engineering, North Carolina State University and Department of Agricultural Engineering, University of Delaware

[a] Annual manure and litter accumulation; typical litter base is sawdust, wood shavings, or peanut hulls

[b] Surface manure cake removed after each flock

[c] Tons/1,000 birds/year

Table 1-7. Typical litter volume after open stockpiling

Bird type	Live weight (lbs)		Total litter[a] production per 1,000 birds sold (tons)
	Market	Average	
Broiler	4.5	2.25	1.0
Turkey grower	25.0	15.0	11
Duck	6.0	3.0	2.2

Source: Department of Biological and Agricultural Engineering, North Carolina State University

[a] Annual house manure and litter accumulation removed to uncovered stockpile to be spread within six months; typical litter base is sawdust, wood shavings, or peanut hulls

from near the liquid surface, taking care not to pick up floating debris or scum. Mix the subsamples in a nonmetallic container and add ¾ pint to an expandable sample container. If the lagoon liquid is being recycled for undercage flushing, a representative sample may be taken directly from the header pipe discharge or flush tank.

Once a representative sample has been collected, it should be either taken to an analytical lab quickly or frozen or refrigerated until it can be analyzed. Some states provide analytical services for free or for a fee at subsidized rates. Commercial laboratories also provide total nutrient and other parameter analyses. Prices vary according to the analysis that is requested.

The results from a regular sampling program should be entered into a farm-specific records database. Once actual farm averages have been developed, they should be useful in making management decisions.

Table 1-8. Typical litter characteristics, as removed from open stockpiles

Manure characteristic	Broiler	Turkey grower	Duck
Density (lbs/ft³)	33	24	50
TS [a] (% w.b.)	61	61	49
VS [b] (% w.b.)	43	44	32
		(lbs/ton)	
TKN [c]	33	32	22
NH_3N	6.9	5.5	4.8
P_2O_5	77	70	41
K_2O	32	30	22
Ca	63	45	34
Mg	8.2	7.1	5.2
S	10	7.4	4.5
Na	6.6	5.7	5.4
Cl	13	8.0	— [d]
Fe	1.8	2.1	1.5
Mn	0.70	0.76	0.56
B	0.039	0.042	0.031
Zn	0.63	0.63	0.50
Cu	0.29	0.42	0.05

Source: Department of Biological and Agricultural Engineering, North Carolina State University

NOTE: All values are on a wet basis (as is). Annual house manure and litter accumulation removed to uncovered stockpile to be spread within six months; typical litter base is sawdust, wood shavings, or peanut hulls

[a] TS = total solids (100 – TS = moisture or water content)

[b] VS = volatile solids; the portion of Total Solids driven off as volatile (combustible) gases

[c] TKN = sum of organic and ammonia(um) nitrogen as measured by the laboratory Kjeldahl procedure

[d] Data not available

Table 1-9. Typical nitrogen losses during handling, storage, and treatment

System	Nitrogen lost (%)
Solid	
Paved collection alley, scraped [b]	30–40
Deep pit [c]	40–50
House litter [d]	25–35
Open stockpiled litter [e]	60–75
Liquid	
Slurry storage [f]	20–30
Lagoon [g]	75–85

Source: Department of Biological and Agricultural Engineering, North Carolina State University

[a] Nitrogen lost during handling, storage, and treatment compared to as-excreted manure nitrogen

[b] Manure scraped from layer undercage paved alley and collected within two days

[c] Annual layer manure accumulation stored on unpaved surface

[d] Annual manure and litter accumulation; typical litter base is sawdust, wood shavings, or peanut hulls

[e] Annual house manure and litter accumulation removed to uncovered stockpile to be spread within six months

[f] Manure, excess water usage, storage surface rainfall surplus; does not include fresh water for flushing

[g] Anaerobic lagoon liquid and sludge

CHAPTER 2

Environmental Regulations and Hazards

U.S. livestock and poultry producers must comply with many federal and state water quality regulations, most of which are related to the following federal statutes:

- Federal Clean Water Act;
- Federal Coastal Zone Act Reauthorization Amendments of 1990;
- Federal Safe Drinking Water Act;
- Federal Food, Agriculture, Conservation, and Trade Act of 1990;
- Federal Insecticide, Fungicide, and Rodenticide Act; and
- other state and local regulations.

All producers should manage their operations to comply with the intent of the regulations. Most states require permits for operations of a particular size, or for those that are having a negative impact on water quality.

Background

The impacts of production agriculture, including animal agriculture, on water quality were historically considered to be natural and uncontrollable. Agriculturally related water pollutants were assumed to be insignificant when compared to discharges of municipal and industrial wastewaters and typically were exempt from water quality legislation and enforcement actions. This policy began to change in the 1960s and 1970s in response to public concern about highly visible incidents, such as fish kills in the Midwest caused by beef cattle feedlot runoff and shellfish bed closures on Long Island, New York that were related to the duck industry.

Environmental and Regulatory Setting

In the past, farmers rarely considered the impact of their management decisions beyond the farm property line. Today, in agricultural areas adjacent to growing suburban populations, fields are often bounded by neighborhoods, schools, or land used for other public purposes. Frequently a delicate balance must be struck by the grower who applies poultry manure to such fields.

Environmental regulation of agriculture is increasing. Three reasons for more environmental regulations for poultry and livestock producers are:

- increased public environmental awareness and concern,
- greater numbers of nonagricultural rural residents, and
- bigger farms with more concentrated poultry and livestock populations.

Programs for agricultural pollution control were initiated in several states as early as the 1960s. Most of today's public programs that target agricultural pollution reach farmers through education, financial and technical support, shared participation in watershed planning, and regulation. Often boundaries and jurisdictions for various public programs overlap in confusing ways.

Comprehensive Nutrient Management Planning

Comprehensive nutrient management plans (see chapter 6, "Nutrient Management") are developed to better manage the nutrient resources directly controlled by an individual farmer. Complete nutrient management planning on a livestock or poultry farm involves many aspects of the farm operation, including the identification and management of major nutrient pathways.

Farm property boundaries usually represent the borders of the system. Nutrients crossing the farm boundary are managed as either nutrient inputs or outputs. Nutrient losses such as through leaching and runoff are generally considered undesirable for both economic and environmental reasons (figure 2-1, page 12). Many states link properly designed nutrient management plans (with regard to manure disposal and utilization) to regulatory requirements.

Watershed Planning

A watershed is the area contributing to a stream, lake, or other water body (figure 2-2). Watershed planning and management efforts are coordinated by public and private stakeholders over areas ranging from tens to thousands of acres. Within a single watershed, there are often multiple land uses and many individual land owners and farm operators.

Computer software is available to model and simulate water and nutrient movement in a watershed. Hydrologic and material transport analysis of a major watershed is a complex task. Models require validation to improve their accuracy, and extensive stream monitoring is difficult and expensive. Usually the first objective in watershed planning is to approximate the flow characteristics of the watershed. Limits on nutrient inputs are developed afterward by evaluating how watershed characteristics affect water quality downstream.

A major challenge to watershed planners is that many water bodies (and their accompanying environmental problems) are not confined to agency or political boundaries. Controversies may occur unless there is interagency or interstate agreement on water quality standards and policy issues. Solving these problems may require arbitration and conflict resolution. A serious challenge faced by nutrient management planners at the watershed level is the lack of clearly defined common goals beyond the farm level.

Political Boundaries and Regulations

Regulations and nuisance laws concerning the land application of poultry wastes can range from local zoning codes and ordinances to more comprehensive state and federal laws. Often, a water quality violation may be difficult to prove, because the water quality standard is not clearly written. Common problems associated with monitoring and testing for local farm waste contamination in lakes and streams include:

- the diffuse location of sites receiving wastes,
- the intermittent nature of surface runoff and the invariably short response time for collection of representative water quality samples,
- large rainfall events that mask contaminants with stormwater runoff, and
- the dilution factor of the receiving water body.

Regulations regarding land application systems should have clearly defined objectives, yet be written to encourage dialogue, cooperation, and flexibility. For example, several types of irrigation systems are available for land application of liquid manure. Some are better suited for certain types of manure mixtures, depending on solids content and type of solids. Some irrigation systems may provide more uniform application of liquid manure on a given site than others, resulting in less probability of surface runoff. Regulations should not be so restrictive that they remove certain irrigation systems from consideration. (For more information about irrigation systems, see chapter 7, "Application Equipment.")

Through the Clean Water Act (CWA), which was passed in 1972 and amended in 1987, the United States has legislated protection for the nation's water quality. Within the provisions of the CWA, each state retains the right of ownership of the water and the authority to define its water rights. States usually retain water use controls through regulations for issuing permits, while local permitting authorities (such as towns) normally control land use. The CWA initially focused on point sources of water pollution by adopting the National Pollutant Discharge Elimination System (NPDES) program, which included provisions for permitting large concentrated animal feeding operations (CAFOs), including poultry operations.

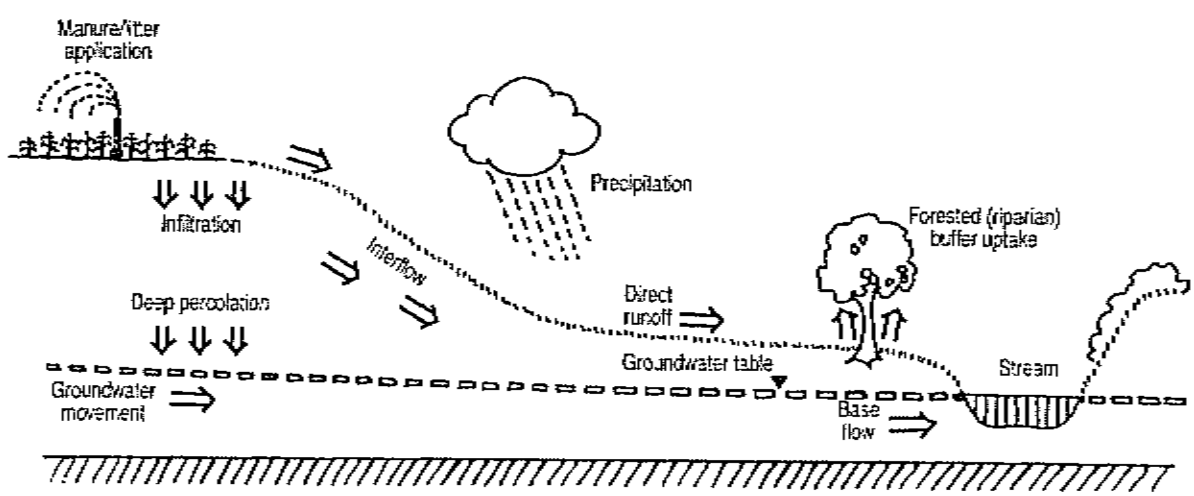

Figure 2-1. Pathways for manure pollutants from agricultural land to water sources
Source: Adapted from *Liquid Manure Application Systems Design Manual*, NRAES–89

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A point source of pollution enters water transport routes at a distinct, identifiable location. Point sources can be easily measured, and their impact evaluated directly. Major point sources include pipe discharges from industrial and sewage treatment plants and effluent from farm buildings or solid waste disposal sites.

The U.S. Environmental Protection Agency (EPA) includes CAFOs in its definition of a point source. The NPDES defines a CAFO as a feedlot with over 1,000 animal units. The term "animal unit" (1,000 pounds of live weight) is not consistent among or within animal species. For example, the term does not translate directly for poultry live weight, largely because of differences in biochemical oxygen demand (BOD) or other manure physical and chemical differences. (BOD is the quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specific conditions. It is a standard test used in measuring wastewater strength.)

The following poultry numbers are considered equal to 1,000 animal units (these are minimum federal numbers; individual states may have more strict standards):

- 100,000 laying hens or broilers (if the facility has continuous overflow watering—a very old system generally not in use today);
- 30,000 laying hens (if the facility has a liquid manure handling system);
- 55,000 turkeys;
- 5,000 ducks; or
- any combination of the above equal to 1,000 animal units.

The requirement for an NPDES discharge permit for a CAFO depends on whether or not it would have a discharge in the case of a 25-year, 24-hour storm (see figure 2-3, page 14). (A 25-year, 24-hour rainfall event is the statistically predicted amount of rain from a storm lasting 24 hours and occurring only once every 25 years.) Discharges that occur only when there is a storm event of this size do not require a permit. Growers with operations larger than 1,000 animal units and who have discharges even without the occurrence of a 25-year, 24-hour storm are required to obtain NPDES permits.

Feedlots with between 300 and 1,000 animal units with a direct discharge through a man-made device (such as a pipe) or with the potential to discharge to a stream are also required to obtain an NPDES permit. However, if a complaint is made, an investigation is usually initiated, and any producer, regardless of the size of his or her operation, may be required to obtain a permit. This often occurs as a result of fish kills traced to a discharge (such as leaching from a litter stack), in which case fines may also be imposed. Having a permit may prevent a producer from being sued under the CWA.

Since CWA legislation began requiring each state to develop and implement its own plan for dealing with livestock wastes, states have interpreted the CWA in different ways. Where the state plans are at least as stringent as the federal requirements (states have the option to be more restric-

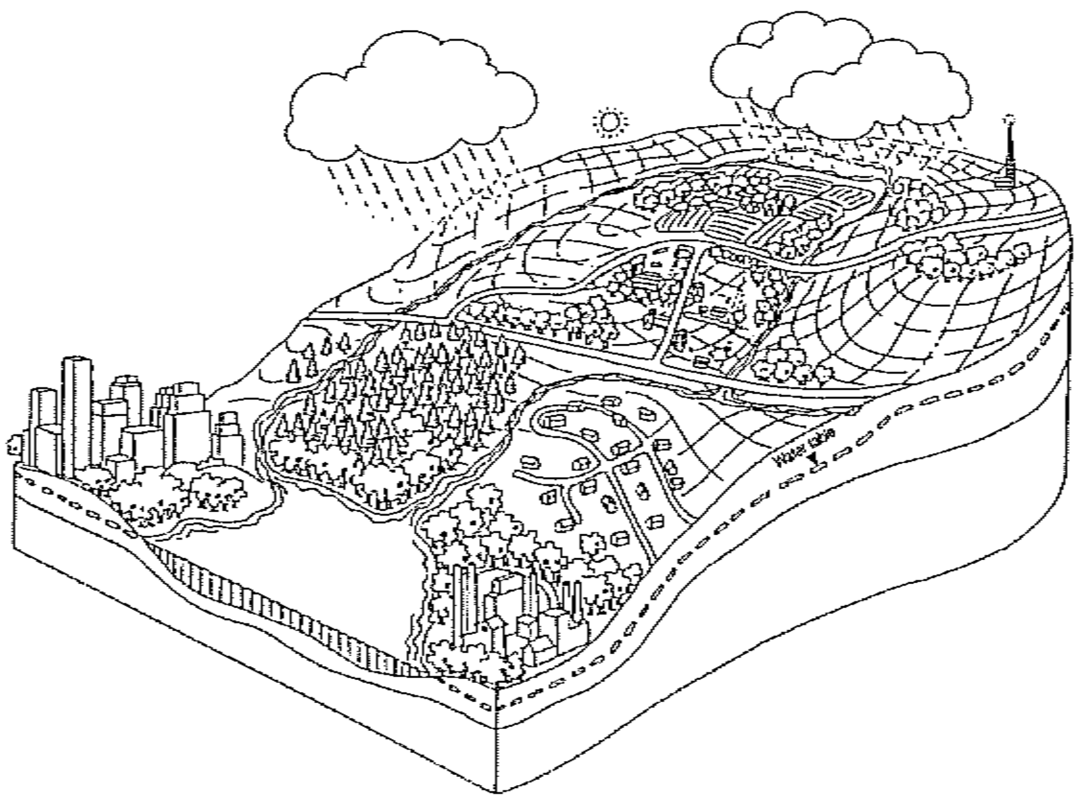

Figure 2-2. A watershed

Source: *Home*A*Syst: An Environmental Risk-Assessment Guide for the Home*, NRAES–87

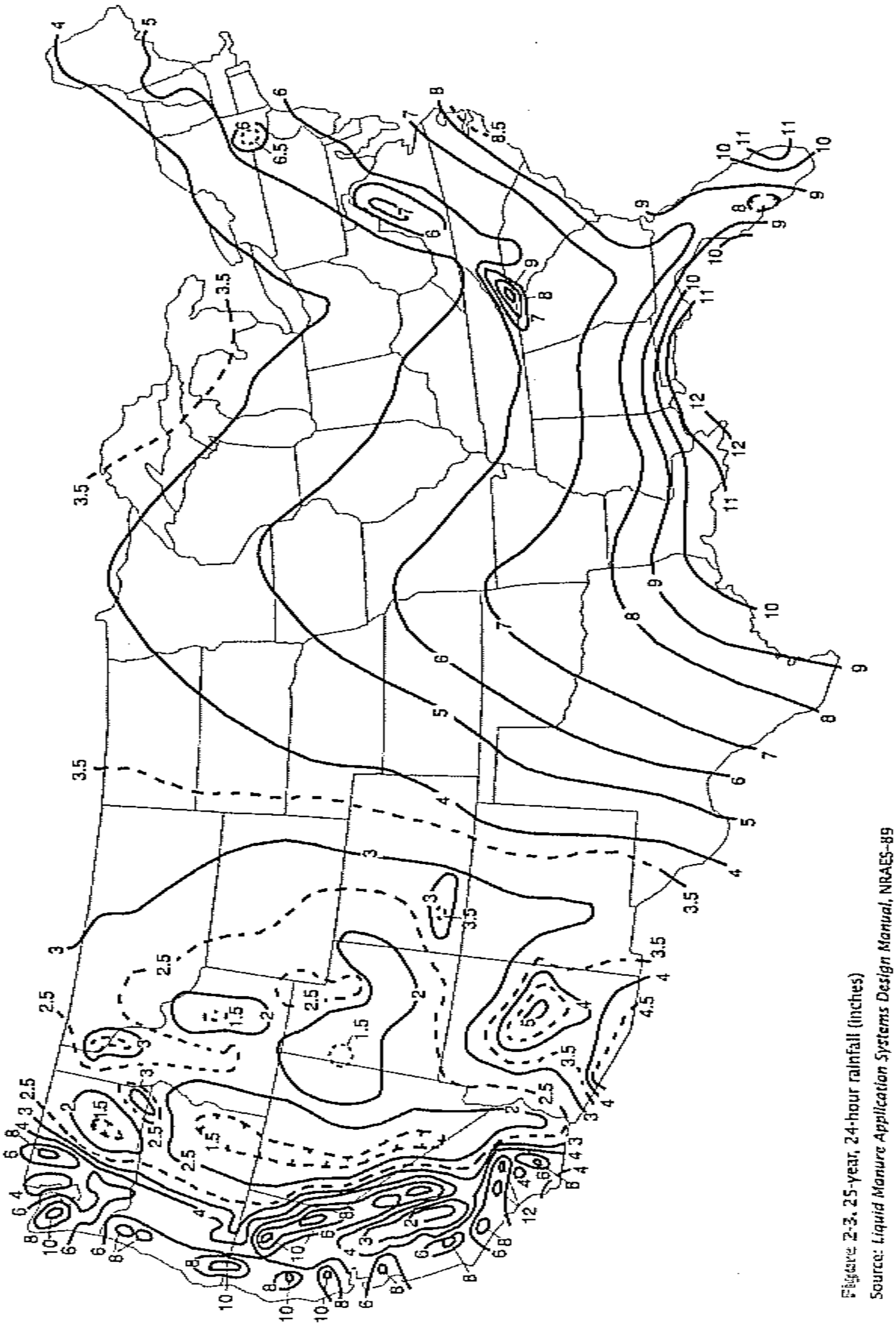

Figure 2-3. 25-year, 24-hour rainfall (inches)
Source: *Liquid Manure Application Systems Design Manual*, NRAES-89

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tive), states receive authority through the EPA to operate their own NPDES permitting programs. As a result, there is considerable variation among states.

Amendments to the CWA issued in 1987 were aimed at strengthening and increasing the emphasis on nonpoint sources (NPS) of water pollution. NPS pollution is defined by the EPA as "the pollution of our nation's waters caused by rainfall or snowmelt moving over and through the ground. As the water moves, it picks up and carries away natural pollutants and pollutants resulting from human activity, finally depositing them into lakes, rivers, wetlands, coastal waters, and groundwaters." In short, the EPA says that NPS pollution is pollution from stormwater and runoff. Unlike point source pollution, NPS pollution is difficult to locate and control.

Once again, the states were given broad latitude to develop and implement their own strategies for dealing with NPS pollution. Most states have started this process by prioritizing water quality problems and defining the likely sources of pollutants causing these problems. Their findings suggest that runoff from agricultural lands, particularly from lands receiving animal wastes, is a leading source of NPS pollution. Furthermore, recent state court challenges suggest that land receiving animal waste applications, not just CAFO feedlots and lagoons, should come under the definition of a point source and be regulated accordingly. Although most states do not yet have specific legislation regulating the amount and location of manure field applications, efforts are underway in many places to tighten permitting requirements.

The Coastal Zone Act Reauthorization Amendment of 1990 (CZRA) includes thirty-five states, twenty-nine of which have Coastal Zone Management (CZM) programs approved by the National Oceanic and Atmospheric Agency (NOAA). These programs, which usually target coastal communities, also have jurisdiction over watersheds that drain into coastal waters. Since federal, state, and local authorities are now focusing more attention on nonpoint sources of pollution, smaller livestock operations in more states are coming under regulatory scrutiny.

On a state-by-state basis, there is a wide range of regulatory structures in place. States differ in terms of which agency enforces the regulations and which regulations are enforced. Most states have followed the federal pattern of regulating larger operations and ignoring the smaller ones. The recent trend is to regulate animal agriculture based on animal concentrations, such as animals per acre or total number of animals. This is particularly true for operations in heavily populated, environmentally sensitive areas. Larger concentrations of poultry or livestock generate more manure and may be more odorous. In sum, the more nonfarm people there are in an area and the larger the concentration of poultry and livestock, the more likely it is that a complaint will be lodged.

Local Regulations

Localities in many poultry-producing areas are developing and implementing poultry facilities ordinances. Most ordinances are aimed at reducing nuisance conflicts between neighbors, providing for orderly growth of local areas while protecting agriculture, and protecting groundwater and surface water resources.

Poultry ordinances typically address building setback distances from public highways, property lines, neighboring homes, incorporated towns, residentially zoned areas, public wells, and other key features. In addition, ordinances specify minimum acreages for single- and multiple-poultry-house complexes and often require nutrient management plans and approved litter storage sites. Poultry ordinances usually require accountability by the producer for all litter produced so that, if sufficient acreage is not available to utilize the nutrients produced at the complex, an approved disposition and written contract is on record. Nutrient management plans and disposition agreements are renewed at specified intervals.

Because of the growing competition for land use in many poultry growing areas, poultry ordinances are likely to become more widespread. These devices can help protect producers from frivolous lawsuits and increase farmer awareness of the value of poultry waste as a resource for crop production and livestock feed.

Private Regulation

Private regulation can take many forms but usually involves lawsuits based on trespassing, negligence, or invasion of riparian (streambank) rights. Perhaps the most common form for poultry or livestock operations is the doctrine of nuisance. One prominent legal authority has noted that there is perhaps no more impenetrable jungle in the entire law than that which surrounds the word nuisance.

Two types of nuisances are recognized by the courts: public and private. When property is used in such a way as to interfere with the rights of a substantial number of people, this may be characterized as a "public nuisance." If only the rights of a few are involved, it will probably constitute a "private nuisance." This distinction may be critical in a lawsuit for an injunction. It may be easier for a plaintiff to win a suit for an injunction where a public nuisance is involved, because the interests of the public may be judged substantially greater than the interests of a private individual. If an activity allegedly threatens many people, government agencies are normally the parties that file a lawsuit alleging public nuisance.

A private nuisance is a nontresspassory invasion of another party's interest in private use and enjoyment of property. It is also an activity "that makes it difficult for neighbors to live there." Property owners have a basic right to enjoy their property without unreasonable interference from another person's or party's activities. Activi-

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ties that cause odors, dust, flies, and noise are all potential private nuisances.

In recent years, all fifty states have passed "Right to Farm" (RTF) and other legislation to help defend against agricultural nuisance cases. The primary goal of RTF laws is to preserve farmland and prevent its conversion to residential uses. Generally, RTF laws do not protect poultry or livestock operations from nuisance lawsuits stemming from pollution or unusual odors. Aside from good local land use controls, perhaps the best practice to guard against nuisance lawsuits is to maintain a "good neighbor" policy.

Regulatory Trends in the Livestock Industry

In the face of current consolidation and integration in the American poultry and livestock industries, more stringent environmental regulations are likely. Especially for the poultry, hog, and dairy industries, increased production in relatively small regions has led to an increasing public sensitivity to livestock pollution issues. Policy response in the European Union over the last decade may give some indication of future livestock regulation in America. In Europe, a stricter regulatory approach has been applied, including production quotas; manure manifests; application standards; and, in some cases, charges or levies on nutrient inputs. At the same time, investment in public and private research for waste processing has increased. Environmental education and local involvement in policy making have also increased. The effectiveness of the European approach has yet to be determined.

In 1994, Ontario, Canada, instituted an Environmental Farm Plan Program based on the Farmstead Assessment System (Farm-A-Syst). Farm-A-Syst was developed in the United States to help farmers assess groundwater quality risks through use of a series of worksheets that cover appropriate environmental topics such as site evaluation; soil, water, and air quality; farm wastes; agricultural inputs; and natural resources. As a result of completing an environmental farm plan, Ontario farmers may avoid future regulation and also:

- safeguard the health of their families and livestock,
- preserve surface water and groundwater quality,
- reduce liability,
- enhance property values,
- plan business improvements or expansions with environmental protection as one of the goals, and
- provide solid information on which to base future environmental assistance programs.

North Carolina, in response to rapid growth in swine and turkey operations and accompanying environmental concerns, has passed numerous pieces of legislation addressing waste management rules for livestock farms. Legislation in North Carolina now requires certification of persons performing land application of animal waste from swine production. Other states are adopting similar requirements.

In 1998, the U. S. Department of Agriculture and the EPA jointly issued a Unified National Strategy for Animal Feeding Operations. This strategy addresses seven major national issues:

- building capacity for comprehensive nutrient management plan development and implementation;
- accelerating voluntary, incentive-based programs;
- implementing and improving existing regulatory programs;
- coordinating research, technical innovation, compliance assistance, and technology transfer;
- encouraging industry leadership;
- coordinating data; and
- measuring performance and determining accountability.

As a result of the national strategy, it is likely that state regulations and policies will continue to evolve.

As watershed planning and NPS pollution issues evolve, more stringent water quality standards and rules are likely to emerge. Growers should get involved in these issues to ensure: 1) that they remain aware of the concerns and risks associated with management of application systems for all manures; 2) that overly burdensome rules are not implemented; and 3) that compliance with regulations can realistically be achieved.

CHAPTER 3

Poultry Housing and Waste Management

Waste management systems are dependent upon the type of layer, pullet, broiler/turkey, or breeder house design involved. Houses are usually either high-rise or single-floor.

The high-rise layer house is normally 40 to 60 feet wide. Sidewalls may be constructed of a drop curtain, a drop curtain with auxiliary fans, or a windowless wall with light and air control (mechanical ventilation). The watering system typically consists of cups or nipples. Manure is collected and stored in a pit under the house. It may be removed any time during the laying or growing cycle but is normally removed when the flock is moved out. Figure 3-1 shows the high-rise concept.

Waste drops directly to the lower floor of the high-rise layer house. If the storage area (lower floor) is properly ventilated, rows of dry mounds or cones of manure will form along the length of the cage area. This system limits the amount of daily labor needed to manage the waste system. Control of all excess water is required. Drinker leakage and blowing rains (with open-sided houses) can turn the manure piles into an unmanageable slurry mix. Maintaining the mounds or cones at less than 45% moisture will assist in fly control.

This system works best with lower level exhaust fan ventilation, which pulls fresh air in through controlled inlets on the top floor; over the birds on the top floor; and down past the manure, taking moisture, stale air, and odors out of the building. Interior circulation fans may also be used in the pit area to improve circulation and promote manure drying (figure 3-2, page 18).

Controlling manure moisture through good maintenance and monitoring of watering systems will help keep manure dry and will make clean-out easier. Manure from the high-rise building can be directly land applied, composted, ensiled for feed, dried in drying beds, or used to generate biogas.

A standard single-story stair-step layer house is 30 to 60 feet wide. Sidewall construction may be a drop curtain, a drop curtain with auxiliary fans, or a windowless wall with light and air control (mechanical ventilation). The watering system may be cups or nipples. Manure is removed with a scraper or by flushing to a lagoon. Flushing is typically done daily for 20 minutes at a rate of 500 to 1,000 gallons of water per minute. Scraping is done two to three times per week. The manure from either mode of removal can be delivered to a storage pond or to a treatment

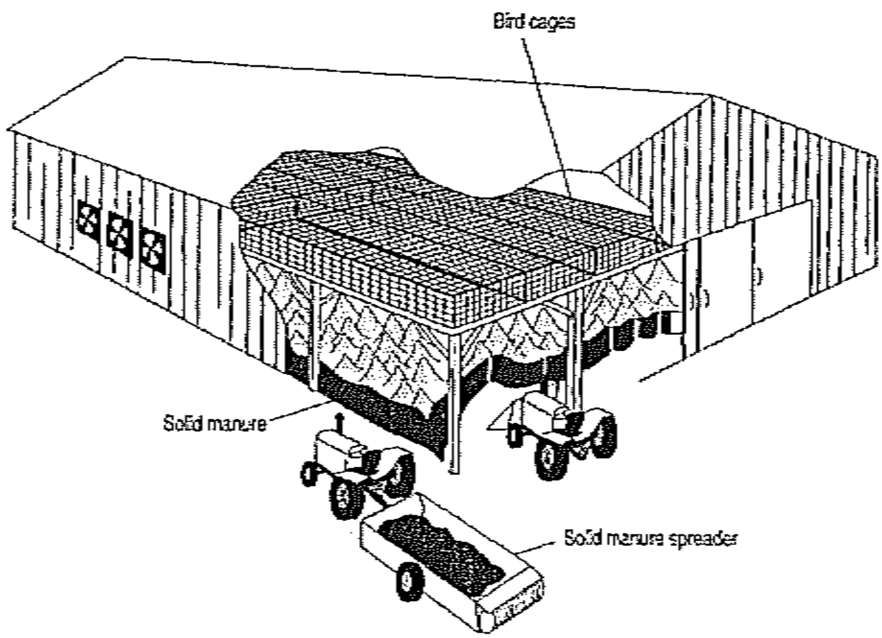

Figure 3-1. High-rise poultry layer house concept
Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

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lagoon. For a flush system, settling tanks or channels can be used to remove the solids, while the effluent is discharged into a holding pond or to a lagoon. Figure 3-3 shows a wide-span caged-layer house with collection alleys (gutters) for flushing or scraping. Figure 3-4 shows a mechanical scraper system for removing manure from under the cages.

In fully automated cage systems, the manure may be removed by a belt system that runs under each tier of cages. Proper management of the system can greatly reduce manure moisture before the manure is removed from the house. Some systems have special ventilation ducts to assist in drying the manure. This system could be used very effectively in a manure composting operation with minimum labor input. Collection alleys are not necessary with a belt cleaning system.

Broilers and turkeys are typically grown on a liter floor housing system. The litter base (sawdust, wood shavings, peanut or rice hulls, and so on) may be changed after each flock, or a built-up litter-based system may be utilized. In some parts of the United States, the built-up litter may be used for 2 to 3 years before cleaning. Figure 3-5 shows a house cross-section that may be used in the production of broilers and turkeys. Clear-span-truss construction facilitates clean-out.

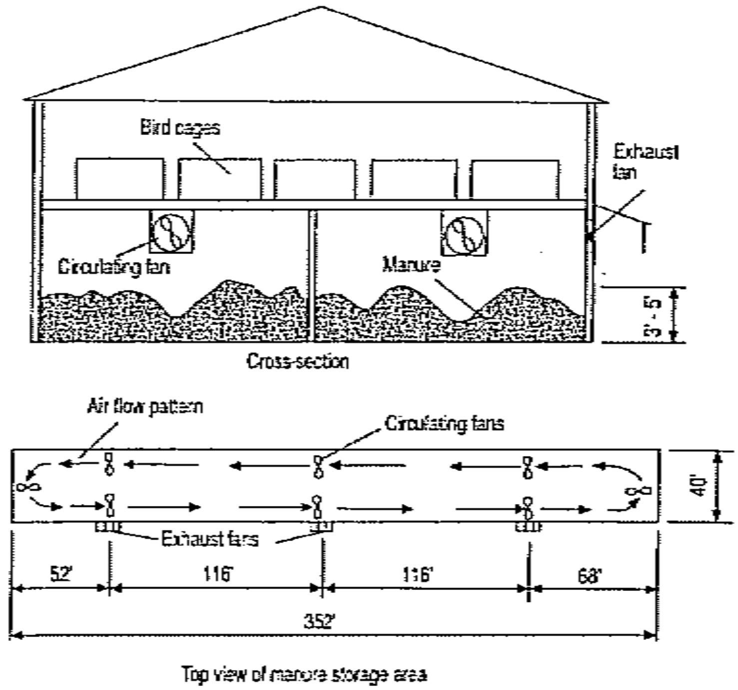

Figure 3-2. Ventilating the manure pit in a typical high-rise poultry building
Source: *Livestock Waste Facilities Handbook, MWPS–18*

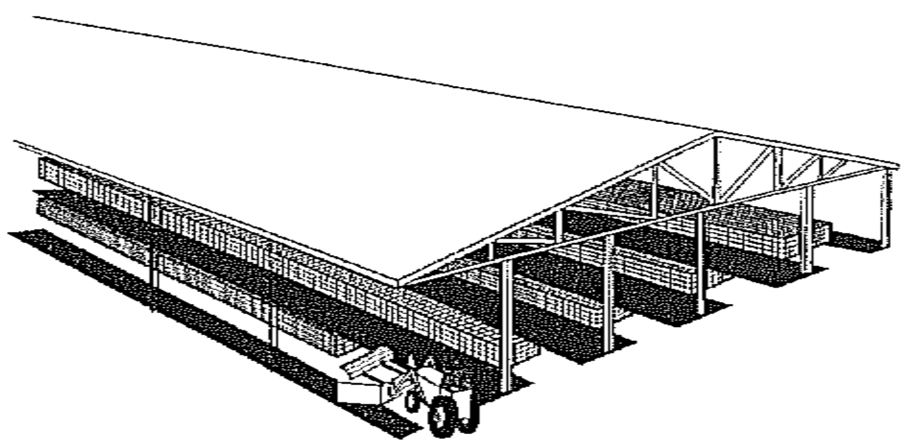

Figure 3-3. Cage layer building concept with connection alleys (gutters) for scraping and flushing
Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

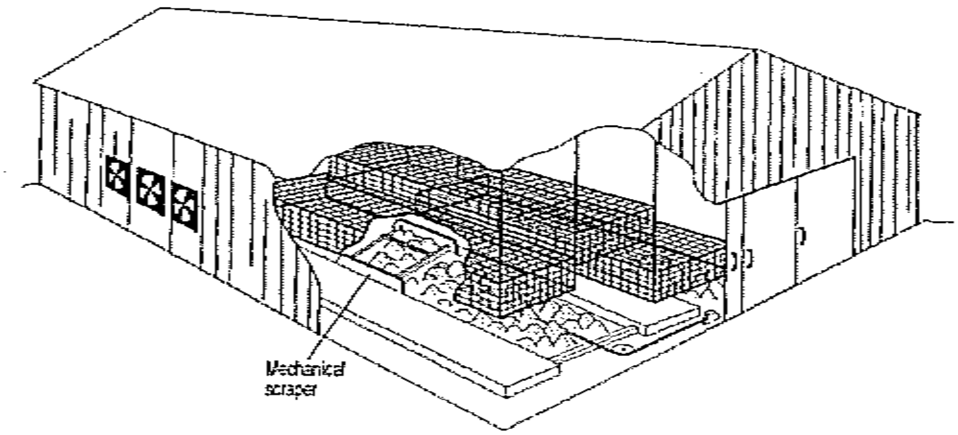

Figure 3-4. Solid waste may be scraped regularly (possibly with a mechanical scraper) from the facility for transport to the field

Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

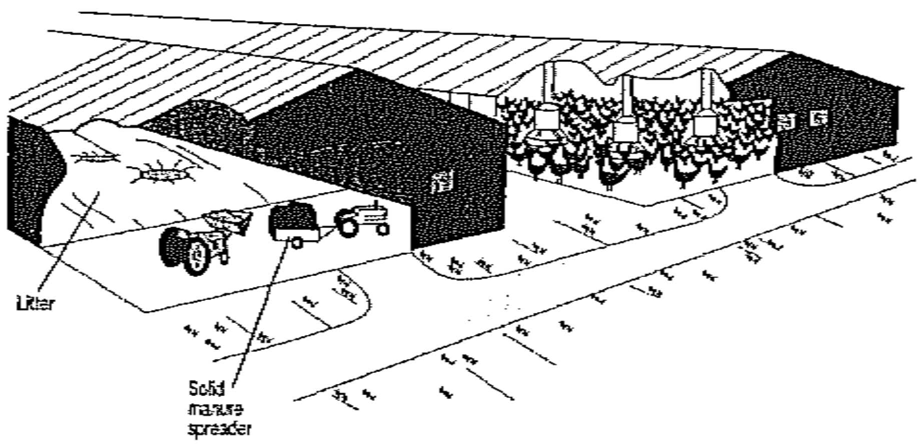

Figure 3-5. Building with litter floor system for broilers and turkeys

Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

CHAPTER 4

Manure Storage

Poultry manure storage allows for optimum use of labor and equipment and provides a means of nutrient retention. Proper manure storage will help provide environmental protection and may help offset storage costs by allowing more effective use of nutrients as fertilizer. Storage also provides future opportunities for the sale of litter for feed or compost feedstock or other off-farm sales. However, depending on the type of storage method or structure selected, the capital cost can negate any economic gain.

Dry manures from birds on litter or cage birds over well-ventilated deep or shallow collection pits can be handled and stored as a solid material. Wet manures from cage birds over belts, scrapers, or flush manure channels are handled as a sticky semi-solid or a liquid, depending on the amount of water in the manure. Wet manure will become anaerobic very quickly and will contribute to high odor levels, especially when it is disturbed and spread. To avoid odors, manure should be kept as dry as possible or should be land applied or processed as soon as it is removed from the house.

Poultry manure storage systems can range from temporary piles to permanent roofed structures. The type of system most useful to an enterprise is dependent on the quantity of manure to be handled, manure moisture content, the frequency or timing of manure movement, the capital investment required, and outside environmental and social factors. Seek advice from your local Cooperative Extension office or Soil and Water Conservation District for assistance with selecting a manure storage facility. The Natural Resources Conservation Service (NRCS) has developed design standards and specifications for poultry manure storage structures.

Solid Manure Storage Systems

Manure Storage within the Poultry House

Solid manure storage starts in the poultry house in both floor litter and high-rise cage-type systems. High-rise houses for caged birds allow accumulation of manure beneath the cages in pits that can be entered with cleaning vehicles from the outside of the structure (see figure 3-1, page 17). With floor litter systems, manure is mixed with the litter by the birds, and storage occurs on the floors through a continuous buildup of a dry litter/manure mixture (see figure 3-5, page 19).

The cleaning frequency of either system is determined by the quality of the manure or manure litter in the house and the amount of remaining storage space available. Wet manures will require more frequent removal than dry manures. Typically, deep-pit and high-rise houses should be cleaned once or twice per year. On the other hand, floor systems might be partially cleaned of wet manure "cake" after every flock but not totally cleaned for a year or more. Poultry manure should be maintained in a dry state so that nutrients are conserved, insects and odors are controlled, bird welfare is enhanced, and handling and storage costs are minimized.

A primary management objective should be to select and operate bird watering systems that minimize water spillage on the manure. For example, an old and obsolete trough-type watering system used with floor birds on litter can produce 20 to 30 cubic feet of wet manure cake per 1,000-bird flock. Closed-system drinkers typically produce less than 1 cubic foot of cake per 1,000-bird flock. In high-rise layer houses, water spillage can turn solid manure into a slurry capable of breaching the containment doors and flowing outside to cause possible environmental damage and costly cleanup. The pit should be inspected daily for signs of spillage, and leaks should be repaired immediately. Often, with large operations, this task cannot be accomplished in a timely manner. Under such conditions, consideration should be given to installing a water collection gutter below the drinkers, so that spilled water can be transported for disposal outside of the manure storage pit.

Reduced water spillage will:

- save water,
- improve the production environment and resulting product quality,
- reduce ammonia release from the manure,
- produce better quality litter containing more nutrients for crop application,

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- reduce the volume of manure to be stored,
- extend the time between clean-out, and
- possibly reduce fly problems.

Additional drying is provided by properly functioning ventilation systems. Reduced ventilation rates during winter contribute to wet manure production. Under cages, air circulation fans within the pit will help remove moisture from the manure (see figure 3-2, page 18). There is a fine balance between heat and moisture with winter ventilation. Too much air exchange increases the heat requirements. However, too little air flow increases manure moisture and the subsequent release of ammonia. A well-insulated building, coupled with a well-designed and properly managed ventilation system, will help maintain the proper heat and moisture balance and help keep litter moisture under control. In addition, better quality litter may be produced, which conserves nutrients and makes the litter more valuable for crop production or other uses. Dollars spent on moisture management provide economic and environmental returns to all phases of bird and manure management.

Manure Storage outside the Poultry House

Storage outside the house is required only when manure must be removed from inside and no land is available for immediate manure application. Cleaning out high-rise pits can usually be scheduled to allow manure applications when needed without additional storage. Caged bird systems with manure removal by belts or scrapers do not provide in-house storage. Floor litter houses are partially cleaned between flocks, while whole-house clean-out is determined by litter management schedules of poultry integrators.

The storage method chosen must protect manure from prolonged contact with rainwater. This requires a surface that sheds water. A deep, well-rounded stockpile of compacted litter, manure, and associated material will shed water. However, the edges of the pile at the ground surface may become saturated and cause surface water and groundwater pollution. Caged-bird manure will readily soak up moisture and should be stored only under cover with confining walls.

All storage systems should be separated from seasonal high groundwater by a minimum of 4 feet of soil or a water-resistant liner of compacted clay, plastic, or concrete. Locate the storage to avoid wells, normally wet areas, runoff or drainage pathways, and other areas of running or standing water. It is also a good idea to provide a grassed buffer around the entire storage area.

Careful storage site location must consider insects, birds, and rodents that can transmit or transfer avian diseases. Storage receiving manure from many different sites should not be located near a poultry production facility.

Floor manure litter contains both wet and dry organic materials that produce heat when stored in confined piles. Storage structures and compact piles may be subject to spontaneous combustion. Avoid piling wet and dry litter together in storage (see "Spontaneous Combustion and Fire Protection" on page 24). Limit manure contact with wood, or provide concrete wall construction.

Temporary Storage

Open Stockpiles

Uncovered stockpiles of floor manure litter can be improved with proper construction. Choose a high, well-drained location away from waterways. Construct piles by dumping manure to form a narrow pile or windrow. The minimum height should be 5 feet, since lower stacks of litter tend to become rain-soaked and difficult to handle and spread. As the stack is being constructed, drive over it with a tractor, truck, or other heavy-wheeled vehicle to provide compaction (figure 4-1). Dump additional

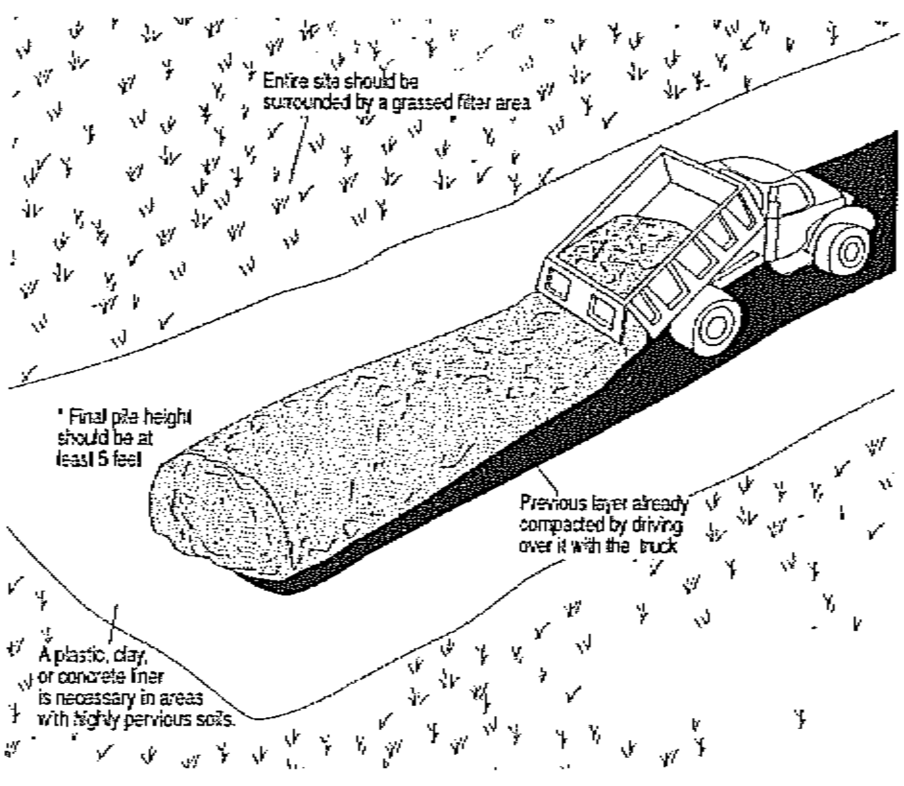

Figure 4-1. Forming a temporary open stockpile with a dump truck

litter by driving on top of the compacted pile and compact again. Widen the pile on each side as it is made deeper. Continue this procedure until the stockpile has a deep, well-rounded top surface with sloping sides of compact manure. Because slightly wet manure will compact better than dry manure, the wetter material should be applied to the pile last to provide a compact surface crust. Where a bucket loader is available, a deep, steep-sided pile or windrow can be formed without compacting the pile.

Covered Stockpiles

Stockpiles of manure can be protected by a covering of plastic sheeting anchored with earth and weights, such as used auto tires. Insect eggs, including those of flies and beetles, are often discouraged by heat and ammonia trapped within a well-covered stockpile of litter. Select the site as indicated above under "Manure Storage outside of the Poultry House." Locate the piles near natural windbreaks, and provide a grassed buffer area around the site. The manure need not be compacted. Make a deep pile with a wide top that is flat or slightly dished. Try to segregate wet and dry manure to avoid conditions leading to spontaneous combustion (see "Spontaneous Combustion and Fire Protection" on page 24). Take care when covering the pile to avoid tearing the plastic. Anchor the ground edges by laying the sheeting edges across a small trench approximately 12 inches deep and backfilling the trench with soil (figure 4-2). Small pools of rainwater will collect on the top of the pile and help hold the plastic in place. Lay old auto tires on the top and tie them in chain fashion with rope to hang down the side slopes. Improperly anchored plastic will become loosened and tear or blow off the pile. Heavy-gauge (6-mil) polyethylene can last one or two seasons. Lighter-gauge material is not recommended.

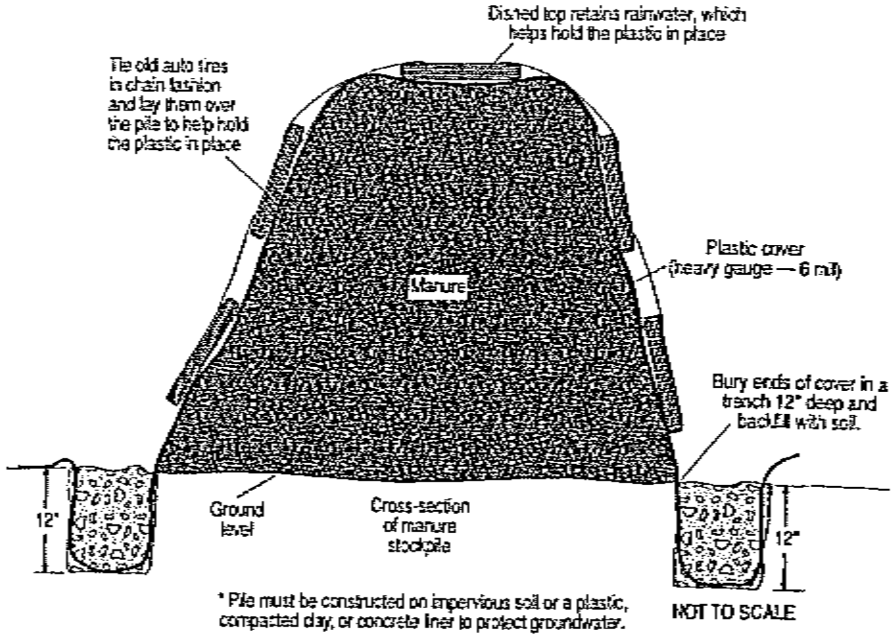

Figure 4-2. Covered stockpile for temporary storage of manure

Stockpiles with Temporary Ground Liners

Where temporary stockpiles must be located on high-water-table soils, a ground liner is recommended to prevent nitrogen from leaching to groundwater. A liner must be accompanied by a cover. The liner should be a sheet of 6-mil polyethylene laid on the soil surface on which the stockpile is formed. Prepare the soil surface by removing any debris that might puncture the plastic. If the soil is loose, provide some compaction with a wheeled vehicle before laying out the plastic.

Apply a 12-inch layer of manure over the plastic before forming the pile to minimize the possibility of tearing the plastic with the equipment tires. A compacted pile can be formed. Fold the edges of the liner 1 to 2 feet up the sides of the pile and anchor it in the manure. Apply a surface cover as described above for a covered stockpile. The ground liner will be torn during unloading of the pile, and new plastic will be required each year. The torn plastic can cause difficulties with manure-spreading equipment, and pieces of plastic liner may be spread across the field. Finding a higher and drier location for pile placement may be preferable to dealing with the difficulties of a temporary ground liner.

Permanent Facilities

Stockpiles with Permanent Ground Liners

If a permanent location for manure storage is desired, a concrete slab can be constructed on which to place a covered stockpile. Using concrete removes the problems associated with a plastic liner. The concrete should be 6 inches thick, reinforced with wire mesh, and placed on top of a 6-mil polyethylene film over 6 inches of compact gravel (figure 4-3). To prevent concrete failure, thicken the perimeter of the concrete to form a footer where traffic enters and exits. Grade the site to achieve maximum underdrainage. An improved gravel roadway will allow stockpile construction during poor soil conditions. Construct a covered, compacted stockpile according to the directions in the previous section, "Covered Stockpiles." Anchor the cover sheet edges on the concrete slab with wood poles, concrete blocks, or other heavy objects.

Bunker-Type Storage Structures

Bunkers are permanent aboveground concrete slabs with two parallel walls of concrete or pressure-treated, wooden post-

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and-plank sidewalls. They are identical to bunkers used for storing silage on livestock farms (figure 4-4). A bunker allows deeper piling and better compaction of manure to reduce the total area required for the manure storage. An endwall can be constructed to slightly increase the storage capacity. However, loading the structure is more easily accomplished without an endwall. A cover of plastic can be attached to the walls with batten strips and anchored with tires. A more permanent cover of reinforced fabric with edge anchorage eyelets and a roll-out crank similar to those used for truck covers can be used. With careful use, storage, and repair, the reinforced fabric cover will last for many years.

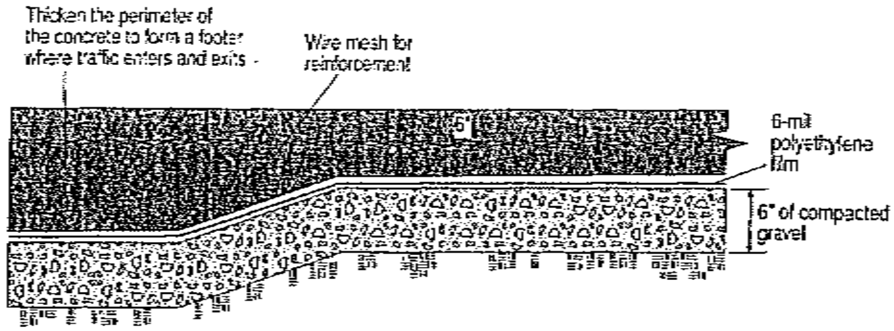

Figure 4-3. Cross-section of a permanent concrete ground liner

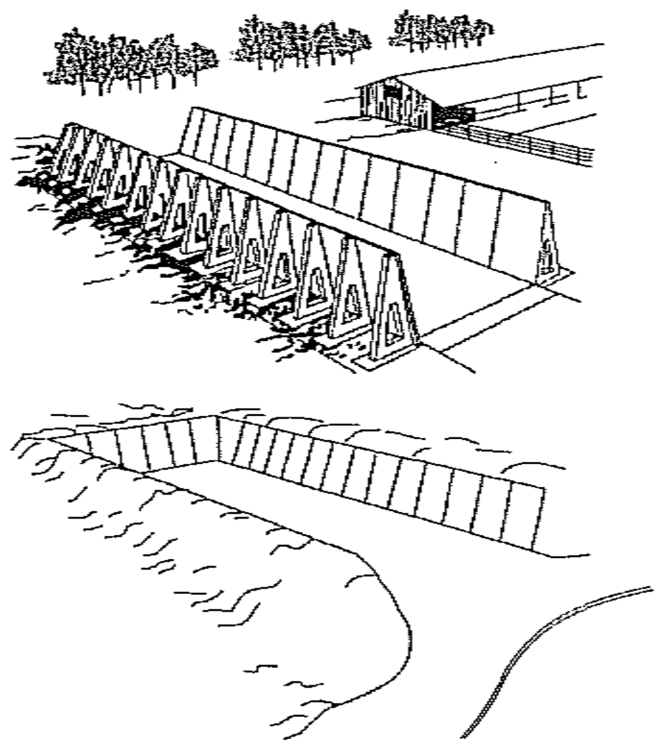

Figure 4-4. Two types of concrete silos that can be used to store manure
Source: *Farm and Home Concrete Handbook*, MWPS–35

Storage Structures with Permanent Roofs

Concrete slabs, bunkers, or other structures with permanent roofs can be constructed to eliminate the need for plastic covers. The roof structure must be a clear span supported by the outside walls or perimeter posts (figure 4-5, page 24). Interior posts will obstruct loading and unloading and might be ignited if spontaneous combustion conditions exist (see "Spontaneous Combustion and Fire Protection" on page 24). Roof structures must be of sufficient height to allow manure piling and clearance for dump trucks, loaders, or other equipment that may be used. Roofs 12 feet or higher may require wall panels or curtains to protect the stored manure from blowing rain or snow.

Building designs may be available from Cooperative Extension offices and the Natural Resources Conservation Service in each state. Cost-share funds are available in many states for the construction of approved manure storage structures.

Permanent Structures versus Temporary Covering

An improved stockpile covered with plastic sheeting provides the best combination of nutrient retention and environmental protection at the lowest cost. This combination of versatility, simplicity, economy, and effectiveness is rarely found in waste management. Manure litter clean-out under an uncertain schedule makes it difficult to plan a manure storage structure. If small amounts of manure are removed regularly, and a large amount is removed only once perhaps every 3 years, a permanent structure capable of holding the entire manure capacity of a poultry farm would remain empty most of the time. The cost of a large permanent structure is unjustified with this frequency of need. A smaller storage would be insufficient during the occasional major clean-out, but it could be supplemented with a temporary stockpile when needed. A single structure can be effectively utilized for multiple houses if clean-out periods are scheduled to disperse the waste load.

Spontaneous Combustion and Fire Protection

Fires have occurred with stored poultry litter as a result of spontaneous combustion in stockpiles and storage structures. These fires are caused by self-heating of the manure due to microbial activity. During heating, combustible gases are released into the air spaces between manure particles. If the concentrated gases come in contact with oxygen at the proper ignition temperature, combustion occurs. Within the pile of manure, incomplete combustion results in a charring of the manure, which is evidenced by a black color when the manure is removed for spreading. When charred sections of the stack are exposed to enough oxygen, an open flame sometimes results.

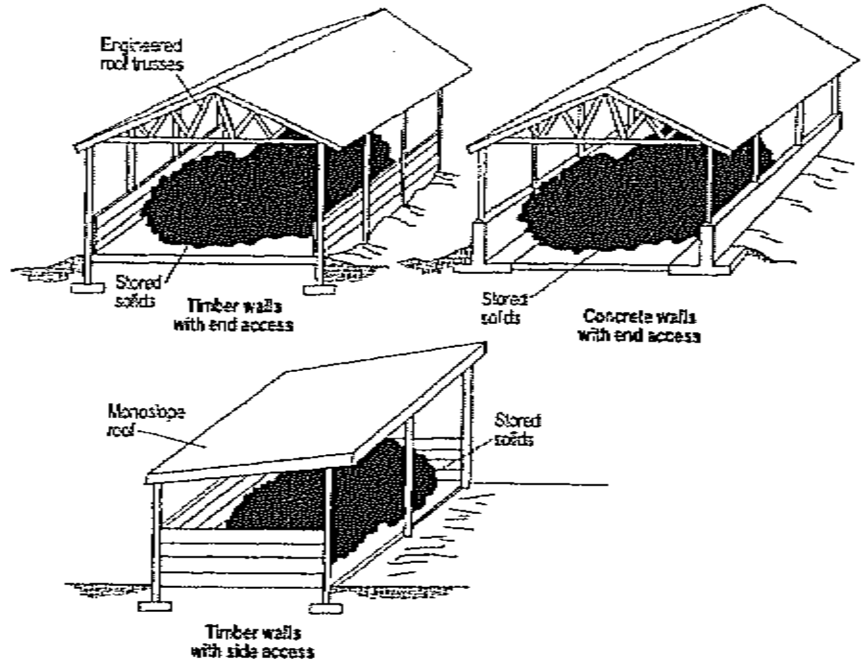

Figure 4-5. Manure storage structures with permanent roofs
Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

Spontaneous combustion is most likely to occur where litter of various ages is compacted together in the same pile. The interface between wet (30 to 50% moisture) and dry litter from different flocks appears to be where combustion starts. Typically, the process occurs at internal regions of the pile 2 to 3 feet from the surface. Spontaneous combustion will occur two to six weeks after making the pile, if there is a problem.

Prevent the possibility of a fire by properly stacking manure. Do not layer wet and dry litter within the stack. Do not layer old and new litter within a stack. When extending the length of a stack, do not place dry litter next to wet litter at the stack interface. Protect litter from blowing rains by using endwalls or sidewalls in a storage structure.

Monitor the stack daily to identify hot spots using a 4-foot-long stem dial thermometer (figure 4-6). If temperatures are above 160°F, be prepared for action. If temperatures reach 190°F, a fire is eminent, and the manure should be removed from the stack and spread out on ground. Have fire-control equipment present when the manure is removed, because ignition and flames may occur. Add water only to extinguish flame, and remove all of the manure from the stack. Simply adding water to the stack may extinguish the flame, but it will also feed the gasification process, resulting in reignition in a matter of hours. Removing and spreading out the manure is the only effective control of spontaneous combustion.

Before constructing a building for litter storage, develop a site plan that allows access by firefighting equipment to the structure. Avoid piling manure more than 3 feet deep next to wooden posts or walls. Make sure that fire insurance is in effect.

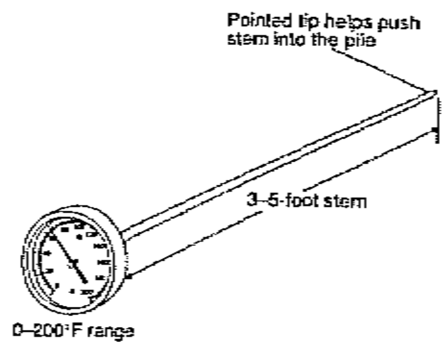

Figure 4-6. Long-stemmed dial thermometer for monitoring stockpile temperature

Liquid, Slurry, and Semi-Solid Manure Storage

Wet manure removed from under caged birds by mechanical scrapers and belts or by flushing with water cannot be stacked and requires containment storage. Manure liquids and slurries that are mostly water (less than 12% solids) require containment in tanks or basins constructed of materials impervious to water transfer. Semi-solid manure (12 to 20% solids) does not readily flow like water but still needs containment walls to keep the manure in a manageable mass. Semi-solid manures can be handled with bucket loaders and open spreaders. Liquid manures must be pumped and spread with tank trucks, tank wagons, or irrigation equipment. See chapter 7, "Application Equipment," for more information.

Manure that is stored in tanks or storage ponds is normally anaerobic and can be expected to generate considerable odor in storage. It is particularly odorous during spreading. If odor is likely to be a problem at the farm site or during spreading, wet storage should not be used, or methods of advanced treatment such as aerobic treatment should be adopted.

Liquid and slurry manure storage can be a constructed concrete or lined steel tank aboveground or below ground or an earthen basin (figures 4-7 and 4-8). Tanks can be open-topped or covered with a roof or top. Earthen basins are usually open-topped but can be covered with a geotextile fabric. Open-topped storage structures collect rainwater, which increases the volume of material to be handled and dilutes nutrients. Open-topped structures are also significant sources of odor, especially when manure enters the structure at the top and when the manure is mixed during unloading. Bottom loading through gravity or pressurized pipe may assist in odor control when manure dries on the storage surface and forms a floating crust.

Semi-solid manure storage can be a tank or basin fitted with a sloped driveway to allow tractor or bucket loader entrance for unloading. The storage is usually open at the top. The entrance of rain and runoff may cause some of the manure to become liquid, which cannot be easily handled with the loader bucket. Methods of allowing water to flow away from the manure, through directed floor slopes and perforated dams, are not very effective with poultry manures. A roof, combined with site grading to direct runoff away from the structure, is an effective means of preventing excessive water in the storage.

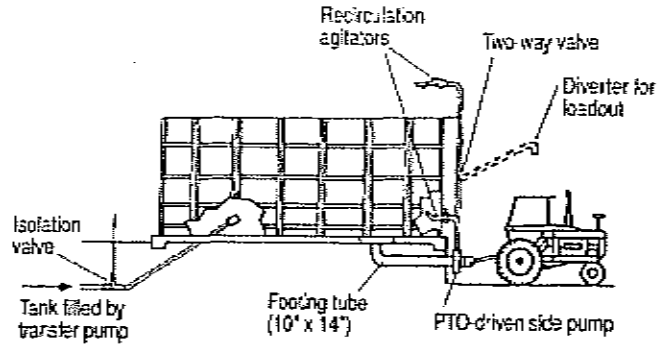

Figure 4-7. Aboveground storage with side pump and footing tube
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

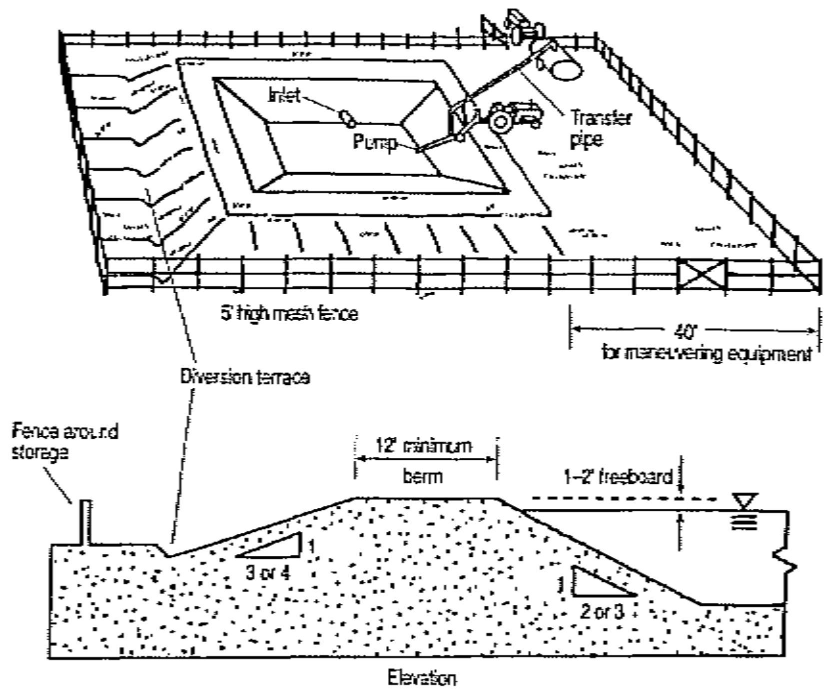

Figure 4-8. Earthen storage pond
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

Wet manure storage structures and basins are subject to high loading pressures on the sidewalls and banks. These pressures increase with manure depth. Wall failure allows the entire contents of the storage to escape and flow overland, which may cause environmental and property damage. Standards and specifications for manure storage construction have been developed by the Natural Resources Conservation Service (NRCS) to ensure design and construction procedures that will avoid structural failure. Although maintenance assistance is currently not a part of the NRCS plans, good maintenance is essential to a successful operation. For more information on earthen storages, see *Earthen Manure Storage Design Considerations*, NRAES–109, which is listed in "Suggested Readings" on page 63.

Maintenance

Maintenance procedures for manure storage are highly dependent on the type of structure and the properties of the manure being held. Maintenance can be described as efforts to ensure that dry manures are kept dry and wet manures are kept contained. Maintenance of solid manure storage systems includes preventing drinker water spillage, optimizing the effectiveness of house ventilation systems, securing outside stack plastic covers from the wind, repairing any damage from wind or machines to permanent structures, and monitoring stored manure temperatures with appropriate control measures employed in fire emergencies. Maintenance of liquid and semi-solid manure storage systems includes periodic inspection of walls to identify cracks or buckling, periodic inspection of earthen banks to identify erosion or animal burrows, and removal of waste in a timely manner so as to keep the design freeboard and storm trapping volume available (figure 4-9). Other maintenance efforts should be identified during the design stage and become part of a maintenance plan. Structural designs developed by the Natural Resources Conservation Service are accompanied by an operations and maintenance manual.

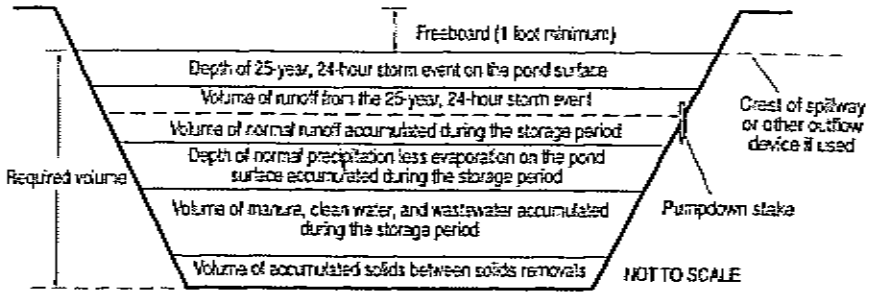

Figure 4-9. Cross-section of an earthen storage basin showing the volumes that must be accounted for in the design

Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

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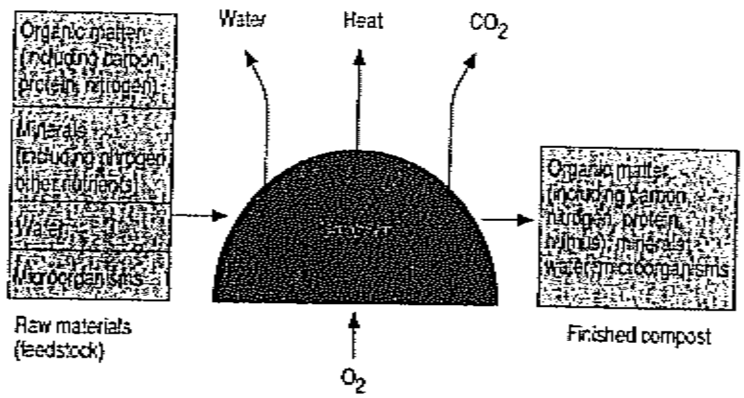
CHAPTER 5

Waste Treatment and Utilization

In many situations, land applying poultry manure as fertilizer is not an environmentally or economically sound practice. In this event, the manure can be treated by some process that changes its physical, chemical, and biological characteristics so that odor, nutrient, or other properties are improved or moderated to allow on-site utilization or transport to off-site utilization points.

Treatment systems utilize biological, physical, and/or chemical processes. All treatment systems require capital investment, management and maintenance costs (which generally exceed the cost of storage), and handling, and often include utilization of the manure as an agricultural fertilizer. However, treatment systems may allow the sale of value-added products and/or the production of usable energy for sale or for operation of the farmstead.



The carbon, protein, and water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of raw material.

Figure 5-1. Aerobic composting: inputs and outputs
Source: *Field Guide to On-Farm Composting*, NRAES–114

Composting

Composting utilizes natural biological processes to break down complex organic matter (manure) into humus. During this process, heat, water, and carbon dioxide are generated (figure 5-1). The heat reduces pathogens, insect eggs, and weed seeds. The nutrients become bound in organic forms, and the manure becomes a dark brown mixture (compost) with a low moisture content and low odor potential and in which the initial material is unrecognizable.

Compost production requires a mixture of materials (ingredients) in measured proportions (a recipe) to provide a balance of nutrients, energy, oxygen, and moisture such that the growth of aerobic microbial populations within the mixture is optimized. The resulting product (compost) can be stored, transported, and utilized in agricultural, commercial, and urban settings without causing undesirable odor or other environmental consequences. Compost production requires space, time, knowledge, management, ingredient materials, and equipment beyond that of customary poultry manure handling equipment.

Composting can turn a waste problem into an environmentally sound marketing opportunity. However, the production and marketing of compost involves management skill equal to and competitive with the management skills required in the poultry operation. Failure to provide for the needed parameters in the composting process may result in increased site odor; groundwater or surface water pollution; and the development of unusable, and therefore unmarketable, compost.

Principles

Composting is a controlled natural process in which diverse organic materials are mixed in proportions to meet the desired nutrient, energy, and moisture contents. The mixture is maintained in an aerobic condition during which heat and water vapor are released. This is the active composting period. After the completion of active composting, a curing or humidification process occurs to produce the desired end product—compost.

Compost can be made utilizing a variety of technologies that range from very simple passive systems to complicated mechanized systems. The process includes mixing materials; placing the mixed materials in a pile, windrow, channel, or bin; monitoring the process temperature, moisture, and in some systems oxygen concentration; aerating the mix through natural convection, forced air, and/or mechanical agitation; removing the composted material to a curing pile or windrow; and finally, preparing the compost for use or sale. The entire process can be accomplished in as little as three months or as long as several years, depending on the intensity of the management and technology employed (greater intensity = shorter time).

The static pile or windrow procedure involves simply forming a pile of compost mix and allowing composting to proceed at a slow rate. The piles are self-aerating by heat-induced air movement through the pile (figure 5-2). This 1- to 2-year process requires little attention.

Static piles and windrows can be aerated using perforated pipes or plenums under the compost, which aids in air passage through the pile. Passive aeration relies on the pipes for air input and the natural convection through the pile as an air-moving force (figure 5-3). Active aeration relies on air pumps to push or pull air through the compost pile, with the exhaust air filtered through a biofilter for capture of any odor (figure 5-4). Active aeration can be automatically controlled by monitoring compost temperature and oxygen concentration. The addition of aeration allows the production of compost in three to five months.

Windrows can be mechanically agitated (turned) with compost turning machines or tractor bucket loaders (figure 5-5, page 29). The process of lifting and dropping the compost replenishes the pile porosity, which aids in maintaining convective air flow through the pile. The production time may range from four to eight months and is lessened as the frequency of turning is increased.

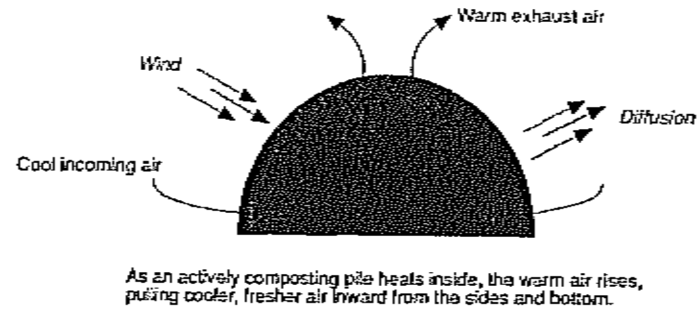


Figure 5-2. Passive aeration
Source: *Field Guide to On-Farm Composting*, NRAES–114

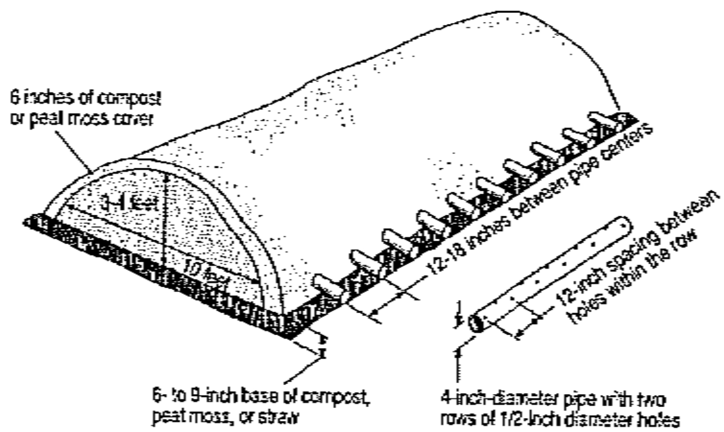


Figure 5-3. Passively aerated compost pile
Source: *On-Farm Composting Handbook*, NRAES–54

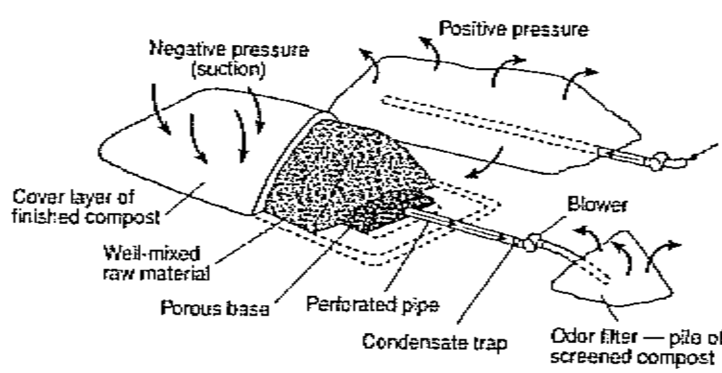


Figure 5-4. Mechanically aerated static pile
Source: *On-Farm Composting Handbook*, NRAES–54

A variety of agitated channels, rotating drums, vertical silos, and other types of reactors with a range of automated process and feedback controls are available. These systems can produce compost in several weeks to two months, but they can be very costly to install and maintain.

Compost Mixtures

A compost mixture or recipe is formulated to provide the optimum conditions for microbial population growth, which results in high heat production and rapid but controlled compost production. Table 5-1

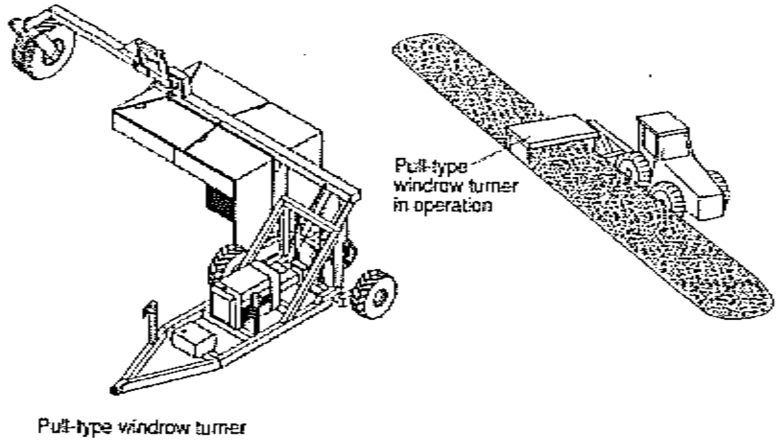


Figure 5-5. Special compost turning machines can be used to turn windrows
Source: Adapted from *Field Guide to On-Farm Composting*, NRAES–114

Table 5-1. Recommended conditions for active (high-rate) composting

[illegible]	[illegible]	[illegible]
Carbon-to-nitrogen (C:N) ratio [a]	20:1 to 40:1	25:1 to 30:1
Moisture content	40–65% [b]	50–60%
Oxygen concentration	> 5%	> 15%
Particle size (diameter in inches)	½ –2	Variable [c]
Pile porosity	> 40% [c]	45–60%
Bulk density (pounds/cubic yard)	700–1,200	800–1,000
pH	5.5–9.0	6.5–8.5
Temperature (°F)	110–150	130–140

Adapted from *On-Farm Composting Handbook*, NRAES–54.

[a] These recommendations are for active (high-rate) composting. Conditions outside these ranges can also yield successful results.

[b] Weight basis (w:w)

[c] Depends upon the specific materials, pile size, and/or weather conditions.

shows the recommended pile conditions for active composting. Poultry manure may require mixing with other organic materials (amendments) to adjust the carbon-to-nitrogen ratio of the mix. Bulking agents (organic or inorganic) may be required to maintain compost porosity for air exchange in the mass.

Of great importance are sources of energy (carbon) and nutrients (primarily nitrogen) for the microbes. The ratio of available carbon to available nitrogen (C:N ratio) is the basis for compost recipe selection. Compost mixes should be started with a C:N ratio of 20:1 to 30:1. Although microbes will grow at other ratios, nitrogen-rich mixtures (those with a low C:N ratio) produce ammonia and odor while carbon-rich mixtures (those with a high C:N ratio) require a longer process time. Typical poultry litter has a C:N ratio range of 8:1 to 16:1, while cage bird manure can range from 6:1 to 10:1. Therefore, to conserve nitrogen and decrease odor, poultry manure must be amended with carbon-rich materials, such as leaves, corn stover, small-grain straw, hay, sawdust, wood shavings, rice hulls, paper, tree bark, cardboard, or other such materials.

The compost mixture must have porosity to provide oxygen to microorganisms. Oxygen is present in the air-filled pore space between the particles of the mix. Bulking consists of adding materials such as chipped wood; rubber; or other stable, blocky material 1 to 3 inches in size to provide better aeration. The need for bulking materials is defined by the compost technology used. Practices that involve frequent moving or "turning" of the mix require less bulking than practices that are passive or that force air through the mixture without moving the material.

The optimum bulk density of a compost mixture is about 55% of the density of water. Bulk density of a compost mix may be determined by weighing a volume of trial mix and then weighing an equal volume of water. If the mixture weighs more than 55% of the water weight, then add more bulking material to increase the air space and reduce the mix weight. Bulking materials, because of their size or chemical makeup, may not be a desirable part of the end compost and can be screened from the finished product for recycling into new compost mixes.

The compost mix must also have a moisture content conducive to microbial growth. The optimum moisture range is between 50% and 60% water. Higher moisture fills air spaces with water, which deprives the microbes of oxygen, resulting in odorous conditions. Lower moisture deprives the microorganisms of water, which stops or slows the compost process. The optimum moisture content of a mix can be judged by squeezing a ball of material in your hand. A squeezed handful of mix should make the palm moist without releasing more than one or two drops of water. If the mix is too wet, add additional dry material or bulking material. If the material is too dry, add water or more wet materials.

The addition of water to a mix should be accomplished during the mixing process to ensure a uniform moisture content throughout the mix. Simply spraying water onto a pile of material will result in most of the water running off the surface with little penetration. To prevent liquid from running down the side, it may be necessary to create a furrow at the peak of the windrow and deposit liquid in the furrow. Some compost mixing and turning machines can be equipped with water application systems.

Some typical recipes for poultry manure compost mixes are shown in table 5-2. Other products can be used in addition to the amendments shown. Also, recipes need not be limited to two-part mixes. However, as the number of different amendments increases in a mix, the calculation of the C:N ratio becomes more difficult and less reliable. Computer spreadsheets and other software are available to assist with the development of compost recipes. Even with computer assistance, the compost recipe should be tested in trial batches and adjusted for optimum response.

Table 5-2. Typical poultry manure compost trial recipes

Proportions for floor bird litter at 35% moisture		
Amendment (moisture content)	Tons of amendment per ton of litter	Gallons of water per ton of litter
Sawdust (40%)	1	120
Leaves (38%)	4	300
Newsprint (6%)	1.5	400
Pine bark (42%)	1	110
Corn stover (12%)	3	600
Straw (15%)	3	600

Proportions for caged bird manure at 70% moisture		
Amendment (moisture content)	Tons of amendment per ton of manure	Gallons of water per ton of manure
Sawdust (40%)	0.6	0
Leaves (38%)	3	80
Newsprint (6%)	1	115
Pine bark (42%)	0.6	0
Corn stover (12%)	2	270
Straw (15%)	2	250

NOTE: Weights are "as is" (wet weight) based on typical moisture content
Recipe = manure or litter + amendment + water

Process Monitoring

An indirect indicator of the compost process is the temperature of the composting material. Temperature is a response to the heat produced by the microorganisms. Well-balanced mixes that are sufficiently aerated and moist generate heat within several days of the start of the process. The temperature within the composting material may peak and be sustained in the range of 135 to 160°F. Compost temperature, measured with a long-stemmed compost thermometer (see figure 4-6, page 24), can be used to discover problems with the compost process. Cool compost is usually caused by a lack of biological activity. This lack of activity often results from (1) a mix with a high C:N ratio, (2) a moisture content and/or oxygen concentration that is too high or too low, or (3) a compost mass that is too small to maintain process temperature (especially during cold weather). Once the cause is corrected, the temperature should increase.

The oxygen concentration within the compost can be monitored with an oxygen probe and meter. Oxygen concentrations less than 5% indicate a need to aerate, agitate, or turn the compost to establish sufficient oxygen to support the desirable microorganisms. Continued low oxygen concentrations will lead to odor-producing conditions. Temperatures may be high during the onset of low-oxygen conditions, but without oxygen correction, the temperature will decline.

Most operators will achieve success by simply monitoring internal pile temperatures and aerating when temperature begins to drop. The active compost process is complete when the compost temperature declines while the oxygen and moisture conditions are at suitable levels, and further aeration or mixing will no longer result in a temperature increase.

Compost Use

Compost can be directly applied to cropland, stored for later use, or further processed for off-farm markets. If the compost is to be marketed as a horticultural product, it must first be cured. Curing is a continued biological and chemical process that stabilizes the organic carbon and nutrients in the compost. Curing occurs in piles over a period of two to three months. Curing is not a drying process, and the initial moisture of the curing compost should be 40 to 50%. Curing piles should be formed to a peak no more than 8 feet high with steep side slopes to shed rain.

After curing, the compost should be screened to remove clods of compost and bulking materials. These materials have not been completely composted and should be recycled to a new compost mix. Cured compost that is pulverized or ground to avoid screening will require additional curing time.

After screening, the compost may be marketed in bulk or bagged for the retail market. Consistently high-quality compost is essential to maintain repeat sales.

Other Considerations

For marketing, there may be specific requirements of the composting site, composting procedures, monitoring and recordkeeping, or compost quality imposed by zoning, environmental, agricultural, or other state and local agencies. Seek the assistance of these agencies, the Natural Resources Conservation Service, and the

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Cooperative Extension Service before establishing a composting operation. For more detailed information about on-farm composting, two excellent references are available from the Natural Resource, Agriculture, and Engineering Service—the *On-Farm Composting Handbook*, NRAES–54, and *Field Guide to On-Farm Composting*, NRAES–114. Both books are listed in "Suggested Readings" on page 63.

Anaerobic Lagoons

Lagoons are bodies of water designed specifically to provide treatment for organic wastes such as poultry manure. Lagoons also provide for storage of the treated wastes, the liquid portions of which can be recycled for waste removal from buildings or field applied as a source of water and nutrients for crops. There can be no outflow to surface streams or groundwater from a poultry waste treatment lagoon.

Farm lagoons fall into two general categories: aerobic (with dissolved oxygen) and anaerobic (without oxygen). Aerobic systems, when designed and functioning properly, minimize odor problems. However, they do not stabilize as much organic matter per unit of lagoon volume, and they must be shallow and have a relatively large surface area to naturally assimilate dissolved oxygen for the aerobic process. Electrically powered surface or subsurface mechanical aerators can be used, but they increase operating costs and complexity. Aerobic processes are rarely used to treat poultry wastes.

Anaerobic lagoons are usually the systems of choice for treating poultry wastes. These systems are designed on the basis of volume per unit of organic waste to be treated and can decompose more organic material per unit of volume than aerobic processes. The discussion below relates to anaerobic systems.

Design Principles

Anaerobic lagoons rely on bacteria that can function without oxygen. These bacteria degrade organic matter that is dissolved and suspended in the water. The bacteria are temperature- and oxygen-sensitive, and the treatment process increases with increased water temperature. Lagoons work better in warm climates than in cold climates. Warmer lagoons can be smaller in volume than colder lagoons for the same waste input. Deep lagoons, insulated and warmed by the surrounding soil, provide desirably consistent water temperature and are preferred over shallow lagoons, which are subject to greater influence from air temperature fluctuations. The minimum recommended water depth is 6 feet. In areas with high water tables, lagoons must be constructed partially or entirely above ground level.

Anaerobic lagoons are designed based on the expected regional temperature and the organic strength of the input waste as reflected by its volatile solids (VS) content. The Natural Resources Conservation Service (NRCS) has established maximum loading rates or minimum treatment volumes based on temperature regions of the United States. Loading rates range from 7 pounds of VS per 1,000 cubic feet of water in Florida to 3 pounds or less of VS per 1,000 cubic feet in North Dakota.

In addition to a minimum treatment volume, a lagoon must provide storage for the waste volume for a period of 120 to 180 days; storage of rainfall (less evaporation) for that period; storage of rainfall from a 25-year, 24-hour storm event (see figure 2-3, page 14); storage for undigested sludge accumulation; and storage of any planned dilution water (figure 5-6). NRCS design procedures should be used to account for these volumes.

Lagoons can be a single basin or a series of basins (or stages). With multiple-stage lagoons, the first or primary lagoon is sized for waste treatment, while the secondary lagoons provide the storage volume. Secondary lagoons provide additional treatment but also collect additional rain water

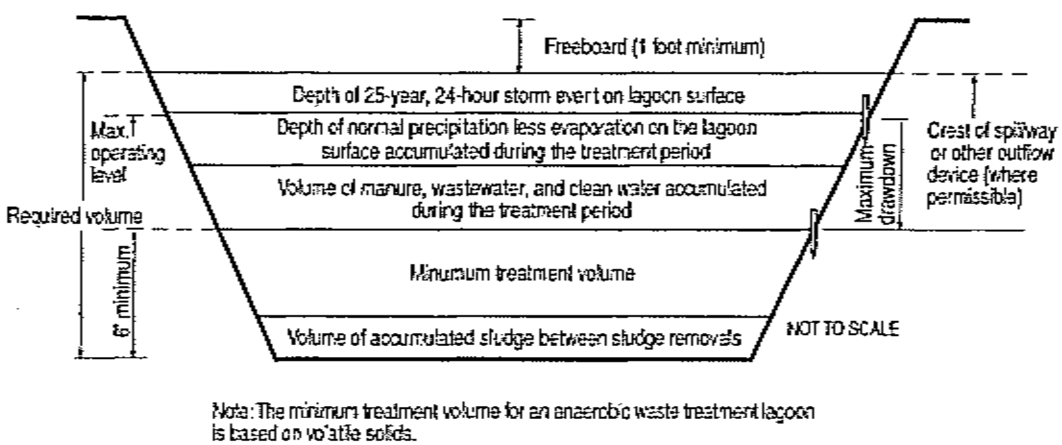

Figure 5-6. Anaerobic lagoon cross-section
Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

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in humid regions or provide additional evaporation in arid regions.

Lagoon treatment volumes can be reduced when waste streams are pretreated by solids-liquid separation with settling basins or screens. The removed solids require additional storage and handling; this may be justified where land area for lagoon construction is restricted.

Pros and Cons

Lagoons provide labor savings by allowing water to be used to collect and transport manure from under cages in poultry houses. The treated water can be applied to cropland with irrigation equipment, which further reduces the labor and energy of waste management. Because of the conversion of organic nitrogen to ammonia and subsequent volatilization losses, lagoons often provide nutrient reduction, which reduces the land area requirement for waste disposal if nitrogen application is the basis for nutrient management. Lagoons also provide long storage times, which permits flexibility in disposal management.

Lagoons may produce odor when subjected to sudden changes in manure quality or quantity as a result of changes in poultry feed or an increase in bird population beyond the design capacity. Odor is also released in the spring and fall seasons in regions of near-freezing winter water temperatures. Poorly constructed or poorly maintained lagoons can leak to groundwater, and failed embankments can cause significant environmental damage resulting in fines and other legal action against the management. Lagoon effluent has a much lower nutrient concentration than manure, but the accumulated sludge in the bottom is typically very high in phosphorus. Although lagoon water is moveable with pumps, there is more of it to move than there is organic solids. Using lagoons and irrigation for waste disposal may require special state or local permits that specify site location, buffer areas, cropland nutrient and water management, and other items. Although it will vary with the specific lagoon, irrigation of poultry lagoon liquids can result in significant odor release.

Lagoon Construction

Lagoon construction should follow the standards and specifications of the Natural Resources Conservation Service, unless they are preempted by local regulations. Requirements include specific site qualities regarding geology, depth to groundwater, buffer areas, embankment height, and other items, as well as definitions of inlets, emergency outlets, materials for impervious liners, and construction details. Construction and operation permits are usually required by state or local agencies. For more detailed information about lagoon construction, see *Earthen Manure Storage Design Considerations*, NRAES–109, which is listed in "Suggested Readings" on page 63.

Lagoon Management

New lagoons or lagoons that have been cleaned should be filled with water to at least one-half their design treatment volume. Startup should be scheduled for the spring or early summer season so the bacterial population has an opportunity to develop before the water cools in the winter. Cold-season startup will result in offensive odors for an extended period of time. Add manure regularly and frequently. Adding liquids from a well-functioning lagoon as a bacterial "seed" will assist in establishing a bacterial population. New lagoons generally require as much as 2 years to become fully operative when loaded in a consistent manner according to their design.

Lagoons must be loaded frequently and at a constant rate. They work best in situations where waste flows are almost continuous, as from sequential flushing of multiple manure collection pits. Infrequent dumping of large flows of manure or clean water into a lagoon may upset biological stability in the lagoon and result in odor production. Odor is the major offending aspect of lagoons and a common cause of friction with neighbors.

The pH of lagoon water should be monitored as a regular practice. Low pH (<6.5) is an indicator of unbalanced bacterial population, which can result in odor. Daily addition of hydrated lime at rates of about 1 pound per 1,000 square feet of lagoon surface should occur as a remedy until the pH stabilizes between 6.7 and 7.2.

Remove liquids from lagoons whenever possible as determined by a nutrient management plan. Always maintain enough storage volume to hold rainfall from a 25-year, 24-hour storm (see figure 2-3, page 14). Unless totally cleaning a lagoon for maintenance, do not lower the water level below that needed for the base treatment volume.

Installation of a depth gauge on a post with maximum and minimum depth marks will aid in defining pumping needs. Account for the pumping rate of the irrigation equipment in judging the time required to draw down the water level in the lagoon.

Aerobic Digestion

An anaerobic digestion process converts organic matter to methane, carbon dioxide, water, and other products through microbial activity in the absence of oxygen. The key microbes require the presence or addition of heat in order to maintain their activity. The methane produced in this process is a combustible gas that can be captured and used as a fuel for the production of heat or the operation of internal combustion engines. The heat or mechanical energy can be converted to electricity (figure 5-7).

Controlled anaerobic digestion of liquid poultry manure in closed digesters can provide organic degradation, odor control, and the production of biogas. Digesters are insulated, airtight containers, usually tanks or covered lagoons, that are tem-

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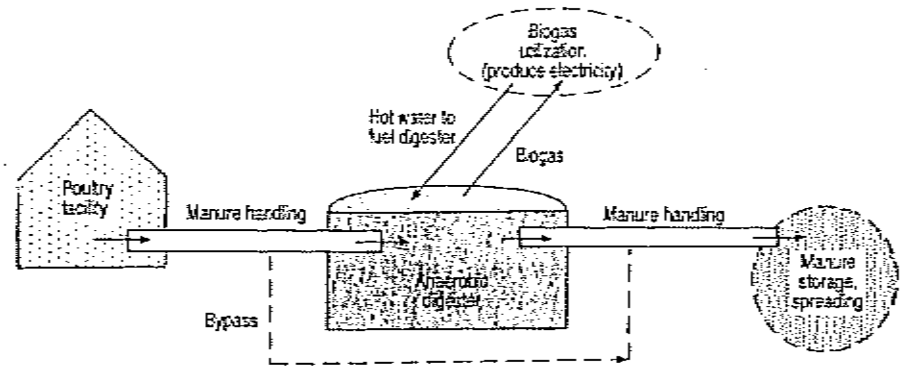

Figure 5-7. Diagram of anaerobic digestion process

Source: Adapted from *Anaerobic Digesters for Dairy Farms*, Bulletin 458, Department of Agricultural and Biological Engineering, Cornell University

perature-controlled to maintain an environment ideal for the growth of anaerobic bacterial populations. The bacteria feed on the manure, changing its physical and chemical makeup while releasing water vapor, methane, carbon dioxide, and other products such as hydrogen sulfide and ammonia.

Principles

An important aspect of anaerobic digestion is that the process is carried out by living organisms. A biogas plant is, in essence, a structural "cow" that requires a consistent feeding program of balanced energy, nutrients, and water at an optimum temperature. Changing nutrient or pH conditions, introducing excessive amounts of antibiotics or toxins, losing heat that results in temperature decline, overfeeding or underfeeding, or any other deviation from required practice may reduce biogas yield or may cause total system failure.

The biogas production rate increases with increasing digester temperature. Past designs in the thermophilic temperature range of 120 to 140°F proved difficult to maintain, because thermophilic bacteria are very sensitive to environmental changes, and the energy required to heat the digester substantially subtracts from the energy produced. Mesophilic digesters maintained at 85 to 104°F produce biogas at a lower rate but require less energy and are less sensitive to environmental changes.

Biogas production is also a function of the time period over which the manure resides in the digester. The longer the residence time (hydraulic retention time, or HRT), the greater the total amount of biogas produced. As the HRT is increased, so is the cost of the digester. Digester designs have usually used an HRT of around twenty days as a compromise between biogas production and cost. Layer manure treated in a twenty-two-day HRT mesophilic digester will require a digester tank size of about 79 cubic feet per 1,000 pounds of birds and may produce 75 cubic feet of biogas per day. However, digester size and gas production are highly dependent on the particular design and quality of manure used.

Covered lagoon digesters provide low-temperature (psychrophilic) biogas production at a low rate, but the long HRT (sixty to eighty days) of a lagoon allows for most of the methane potential of the manure to be realized. Lagoon digesters have an added benefit in that the biogas is cleaner and 10 to 15% richer in methane than biogas from a tank digester. Advances in the development of lagoon covers and gas collection systems are expected to continue as the economic advantage of lagoon digesters becomes more apparent.

There is practically no reduction in the volume of manure that must be stored, disposed of, or utilized after anaerobic digestion, and the digester contents will be greater than the raw manure input, since dilution water is necessary in the process.

Energy Use

The ability to utilize or sell biogas-produced energy has a significant impact on the economics of the process. Biogas is used as a replacement heating fuel for boilers and furnaces, or for the production of electricity through use as a fuel in an internal combustion engine that drives a generator. Only about 70% of the biogas produced in mesophilic digesters can become usable heating fuel; the remainder is directed back for digester heating. If electricity is produced, efficiency losses in cogeneration will provide marketable energy of 20 to 30% of the biogas potential. The remainder will be lost as heat, which can be reclaimed to supply the digestion process or for other heating uses.

Biogas has a low energy density of 19 to 22 megajoules per cubic meter (MJ/m^3) (500 to 600 BTUs per cubic foot). The most viable alternative is to consume the gas as it is produced. Because most situations do not have a consistent need for heat (other than the need to maintain digester temperature), some of the energy may be wasted. Biogas can be compressed at reasonable pressures but not liquefied. Storage of biogas energy is volumetrically inefficient. One volume of diesel fuel holds the same amount of energy as 130 volumes of compressed biogas at 1,380 kiloPascals (200 psig).

Most farms do not have a consistent requirement for electricity throughout the day or year. During periods of low electricity use, some biogas-produced electricity may be sold to the electric utility. During periods of high electricity use, all biogas-produced electricity may be used, and possibly some utility electricity will be purchased. Usually electricity sold to a utility is priced at the replacement value of utility fuel, which is only a fraction of the charge for buying electricity from the utility. The most valuable use of biogas-produced electricity is in avoiding the high cost of purchasing electricity from a utility.

The net predicted economic return for biogas production and conversion to energy is highly dependent on the facility capital and maintenance costs, the use or sale of the energy, and the use or sale of the digested manure. The actual economic return is influenced by the degree of management and maintenance attention given to the details of operation.

The economic return from the energy produced is marginal. Typically, a term of 7 to 10 years has been required before energy income exceeds fixed and variable costs. However, well-designed systems can be expected to have a useful life of 15 to 20 years and would provide profitable operation for half of that life. This economic situation may be satisfactory on a farm that is intended to exist for many years and that can survive short-term economic loss. However, investor capital requires a greater, more rapid rate of return, which almost eliminates the feasibility of investor-financed biogas facilities.

Advantages and Disadvantages

The process relies on anaerobic bacteria to degrade manure in a closed system, which provides process odor control. The digested manure has a low odor level. Plant nutrients are conserved, and the digested manure has a fertilizer value approximately equal to that of the input manure. Biogas production will not reduce the nutrients that need to be managed on the farm.

Anaerobic digesters have been plagued with problems in the past. About 60% of the systems constructed since the middle 1970s in the United States have failed. The technology must be considered transient, as new solutions are being developed to overcome problems with materials handling equipment, gas utilization, cash flow, net economic return, and management skill. Covered lagoons show promise as lower-cost digesters, but it is difficult to practically manage their temperature. Therefore, their potential is greatest in warm regions.

The most profitable biogas plant operators convert or utilize every possible part of the manure and energy into sales or avoided costs. Excess heat energy normally lost from the process is utilized in special ventures such as greenhouse or aquacultural heating. The digester liquid fraction is bottled as a nutrient amendment. The solid fraction is dried using excess heat and bagged or blended with compost for sale as fertilizer to gardeners. These activities require the development of specialized markets and additional investment but increase the economic return from the manure. It should be noted that these auxiliary enterprises often require as much or more management than the base animal enterprise.

There is a renewed interest in biogas production for environmental protection. System construction and operation are considered environmental protection costs for reducing odor emissions or reducing other gas releases to the atmosphere. This approach alters the economic analysis such that the marginal return from energy may be more acceptable.

Digesters are adaptable for the treatment of liquid waste with a solids content less than 12%. It is impractical to liquefy dry waste solely for the purpose of retrieving methane for the production of energy. Incomplete anaerobic activity occurs in liquid manures and results in release of odors during storage and field application. The problem of odors is acute where liquid manure from a large number of animals is stored. Complete anaerobic digestion reduces the volatile components of the manure, resulting in a treated effluent that can be stored and later applied to cropland with reduced odor. Where odor control is required for the operation of the animal enterprise, the production of energy may be of secondary importance. Some anaerobic digestion systems have been installed without the energy conversion component to obtain a reduction in farm odor level.

Direct Incineration

Dry manures can be burned either alone or with other fuels for the production of heat. The heat can be used for space heating, industrial processes, and generation of electricity. Manure has greater energy value as a direct burn fuel than as a biogas source, because almost all of the energy in the manure can be released through burning. The amount of this energy actually captured is dependent on equipment efficiency and manure moisture content.

On-farm use of heat energy from burning poultry manure is limited by the energy demand cycle and the design of small furnaces. Seasonal heating of the farm residence and animal structures is feasible. This may require only a small portion of the manure generated on the farm and may not be a total solution to the waste disposal issue.

Burning raw broiler litter in small conventional furnaces has presented problems of incomplete combustion, slag formation on the grates, odors, particulate emissions, and loading difficulties. A potentially difficult problem is that most of the nitrogen in the manure is volatilized into unknown forms for release, along with other compounds and particulates, as stack emissions.

Manure could possibly be used as supplemental fuel in large coal-burning electric generation plants. Some electric companies have investigated using broiler litter with coal but have abandoned the idea. One trial failed because of slagging in the bottom of the furnace. Another problem was the inability to ensure a reliably large and inexpensive supply of manure when contracting with a large group of farmers on an individual basis. Successful enterprises have been reported in the United Kingdom, where one plant relies totally on poultry litter as fuel to generate electricity.

Approximately 2.6 mass units of broiler manure at 30% moisture would be required to supply the same energy as one mass unit of coal. The bulk density of broiler manure is less than half the bulk density of coal. Therefore, five to six volumes of broiler litter would be required to replace the energy available in one volume of coal. Considerable change in materials handling and storage would be required to facilitate reliable use of broiler manure as a coal substitute. It is difficult to predict a savings for the utility when the amount of material to be handled must be increased by sixfold (unless the utility is paid to receive that material). Without the assurance of an economical and reliable broiler manure fuel supply, the investment in changeover facilities is at great risk.

The failure of conventional industrial burners can be overcome by thermochemical gasification of the manure and combustion of the gas ("producer gas"). In this process, manure undergoes incomplete combustion in a limited-oxygen atmosphere (very much like the spontaneous combustion process described for solid manure storage on page 24). A variety of gasification burner systems are available. A small on-farm system for heating and several central electric power stations have been developed in England.

Broiler litter can be used as supplemental fuel in biomass-burning facilities and waste-to-energy systems for burning urban garbage with little change in facility operation. Litter may be of value for improving the consistency of the energy content of the garbage mix in a waste-to-energy plant. These plants normally have exhaust scrubbing equipment so that nitrogen can be captured.

Inorganic ash from burning litter can be utilized as a soil amendment and may have some fertilizer value that can be used to generate additional income. However, mixed ash from waste-to-energy facilities requires disposal at approved landfills, or other alternative uses, and generates additional cost. Because burning manure destroys organic matter, the long-term consequence may be a general reduction of agricultural soil organic content, assuming the manure would have been used as fertilizer.

The current economic situation in the United States with the relatively low cost of petroleum fuel hinders the adoption of expensive thermochemical conversion processes. Thermochemical conversion may be a least-cost alternative in concentrated poultry-rearing areas, where manure disposal is an environmental problem.

CHAPTER 6

Nutrient Management

Land application is a responsible method of using manure from poultry operations. Poultry manure can improve the soil through the natural recycling of nutrients for plant growth and through the addition of organic matter that improves soil tilth. When managed properly, land application of manure can be used to sustain intensive crop production while minimizing external fertilizer inputs. However, the soil and water systems that are used to recycle manure have limitations that must be recognized and accommodated. Otherwise, the land application of manure may distribute nutrients, organic matter, and pathogens in a way that degrades water, soil, air, and crop quality.

Responsible land application begins with proper site selection. Site evaluation should be driven by the goal of preventing pollution while maximizing the use of nutrients. The environmental regulatory climate with regard to land application of animal manures has become increasingly strict as a direct response to concern about the public's health and welfare. A poultry grower has an added concern: the economic well-being of his or her operation. The outcomes of both concerns depend upon the wise use of resources under the direct control of the grower.

Reducing nitrogen and phosphorus enrichment of groundwater and surface waters has become a societal goal. National and regional water quality concerns, in combination with nutrient management regulations adopted in many states, have created awareness about the need for efficient nutrient management in agriculture.

Good nutrient management planning:

- matches the nutritional requirements of growing crops with leftover nutrients in soil,
- substitutes poultry manure for crop nutrient needs to the extent possible,
- accounts for green manure crops plowed into soils,
- makes up nutrient shortfalls from the above sources with careful inorganic fertilizer applications, and
- maximizes feeding efficiency to reduce nutrients excreted by poultry.

In this way, pollution of groundwater and surface waters is minimized. Overapplication of nutrients increases the potential for nutrient losses into air and water resources. The most efficient and competitive farmers recognize this, and regulatory agencies are increasingly requiring nutrient management planning. The lack of farm nutrient management planning often results in poor utilization of on-farm resources and purchased inputs.

To be successful, a nutrient management plan must combine knowledge about:

- nutrients entering, leaving, and remaining on the farm;
- nutrient application schedules — to ensure that the rate and timing of manure and fertilizer applications are in concert with crop requirements;
- crop selection and rotation — to improve nutrient utilization and reduce runoff and erosion; and
- poultry management and ration balancing — to minimize nutrients excreted or to ensure efficient recycling from birds to crops, and then back to birds.

Farm Nutrient Balance

Farmstead nutrient management involves balancing "inputs" and "outputs" of nutrients for the total farm. Farmers should recognize the quantity of nutrients entering, leaving, and remaining on the farm to begin to understand nutrient recycling. This will help determine management options to make best use of resources and to minimize losses into the environment.

Nutrients are usually brought on the farm in purchased products such as feed and fertilizer (figure 6-1). Additionally, conversion of atmospheric nitrogen (N) by legumes and N contained in precipitation are other sources of farm N. Nutrients ideally leave the farm in products sold such as crops, meat, and eggs. When the system becomes unbalanced, nutrients are more likely to leave the farm in runoff, by leaching into groundwater, or in eroded sediment. When farm production is not tied to feeds grown on the farm, it becomes critical that excess nutrients be transported to other farms so they can be utilized as fertilizer or animal feed.

Available land is the most serious limiting factor for nutrient planning where poultry litter and manure are involved. Based on

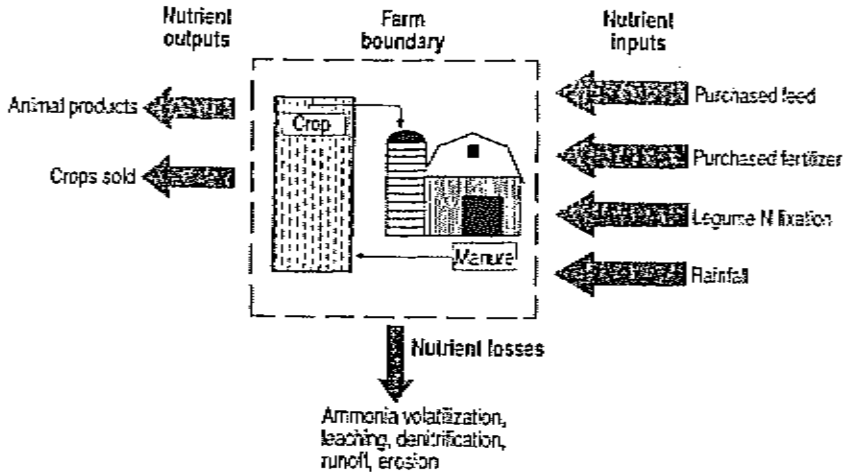

Figure 6-1. Nutrient pathways on a typical poultry farm

Source: Adapted from *Liquid Manure Application Systems Design Manual*, NRAES–89

nutrient content, adequate land must be provided for effective utilization of litter and manure. On farms with high bird densities, litter may provide more nutrients than can be utilized on the farm with the land and crop rotations involved. Alternatives to lack of land include more complete waste treatment, composting, processing into other fertilizer products, and off-site utilization. See chapter 5, "Waste Treatment and Utilization," for more information.

Limiting Nutrient

Nitrogen (N), phosphorus (P), and potassium (K) are the major plant nutrients in litter and manure that are normally managed. Nitrogen is one of the key plant nutrients in poultry and other organic wastes. It is also a major pollutant in excess amounts and is highly mobile, moving with water through leaching and runoff.

Phosphorus is leachable to a lesser degree than nitrogen, but it is an important source of surface water pollution through attachment to sediment and solubility in runoff. A major problem with phosphorus is that a relatively small amount is required by crops. When the litter or manure is applied at rates high enough to satisfy all crop N requirements, P tends to accumulate in the soil over time. As P levels in the soil become elevated, losses through erosion become more and more serious, although solubility in groundwater and runoff may also be of concern with some soils.

Potassium is moderately soluble in water and can be transported in runoff or by leaching. However, it is generally fixed in most soils through reactions with soil calcium, sodium, magnesium, and ammonium. When applied at agronomic rates, K is not generally associated with water quality problems.

Nutrient management plans, which include manure and other organic wastes, should be based on either N or P as the limiting nutrient. The accumulation of P and K in soil can be monitored through soil testing. On the other hand, N does not appreciably accumulate in soil, and much of the soil N can be lost by leaching and denitrification. Further, soil N cannot be easily monitored through soil testing, since the availability of N in the soil is difficult to measure and predict due to complex N reactions in the soil system.

Soils that have regularly received litter or manure applications over time based on crop N requirements are frequently high in P. This is due to the typically unfavorable ratio of N to P in animal and poultry wastes compared to the N to P ratios usually required for crop production. Often these soils are located in regions where high concentrations of poultry and other livestock are found. If studies indicate serious environmental impacts of high-P soils, the land base for many growers will be inadequate, and growers will be forced to find other off-farm uses for their farm wastes. A few states have already adopted a P basis for manure and litter applications.

For the present, many growers will develop nutrient management plans based on N as the limiting nutrient. It may not be practical to limit applications to a P basis, since sufficient acres would not be available for satisfying disposal requirements. However, it is important to monitor soil P levels and manage fields to prevent P levels from rising too high. Management methods available include application to fields that have not received litter or manure in the past, crop rotations to "mine" P in years where fields do not receive litter or manure, use of feed additives that improve efficiency of feed-contained P, and export of litter or manure to predominantly non-poultry or non-livestock areas.

Farm Nutrient Management Plans

Many states currently provide technical support for farmers to develop whole-farm nutrient management plans. While many farmers may be comfortable developing their own plans, regulations in some states may require that a total strategy for nutrient management be developed and certified by state officials.

The most simple nutrient management planning principally focuses on applying litter or manure in place of commercial fertilizer. More sophisticated plans consider a number of other factors that may also be important. Records should be kept on a field-by-field basis to be sure that proper credit is given for accumulation of "leftover" nutrients. This will ensure accounting for the predicted rate at which the various forms of organic N are mineralized to available N for the litter or manure in the year that it is applied, as well as for previous years' applications. This information will be of value in the year-to-year planning process and in reconciling effects of manure applications with soil test results, crop yields, and other farm performance measures. Adjustments will be required from time to time if the plan is to be successful. Development of a comprehensive nutrient management plan and records should include the steps discussed below.

Determine Animal/ Poultry Density

It is important that enough cropland be available to meet the utilization needs for the manure from the livestock and poultry being grown on the farm. An increase in the number of animals will require a corresponding increase in the cropping intensity required for utilization. This might involve an increase in acreage, a change in crops produced, or adoption of multiple cropping systems. Appropriate animal-to-land ratios help prevent excessive applications of nutrients and may encourage the use of homegrown feed, thereby reducing the import of nutrients in purchased feeds. If this principle cannot be adequately met, it will be necessary to offset crop acreage limitations by exporting litter or manure for use on other farms that can appropriately utilize the manure nutrients.

Analyze Feed and Balance Diets

Poultry feeding programs can have a major impact on the manure nutrients that must be managed each year. Overfeeding nutrients is not economical or environmentally sound. Use feed analyses to monitor the quality of feed and to ensure that diets are properly balanced. Become informed about research developments in poultry nutrition and management that may help reduce the excretion of nutrients in bird feces. Enzymes are now available that enable lowering of mineral P in bird feces; they may be commercially feasible for larger poultry companies.

Determine the Amount of Manure Produced and Collected

This will aid in estimating the quantity of manure and nutrients that must be managed in the land application program. Estimates of manure production are available from many sources. Refer to tables 1-1, 1-3, and 1-6 in chapter 1; other production data are available from ASAE and the Natural Resources Conservation Service. If available, use your own records for the quantity of manure removed from production buildings or removed when buildings are cleaned between flocks.

Analyze Manure to Determine Nutrient Content

Periodically have manure samples analyzed for nutrient content. Analyses should be done frequently until a farm trend is clearly established. The amount of nutrients may vary considerably from farm to farm. Some typical values are shown in tables 1-2, 1-4, 1-5, and 1-8 in chapter 1. The method of management and handling of manure will determine to a large degree its value as a plant food. Similarly, the level of management of the poultry house (frequency of litter change, moisture in litter, ventilation, and other related factors) will influence the retention and forms of nitrogen contained in house manure. The procedures given in table 6-1 may be used as a guide for estimating nutrient content, but the most accurate way to determine the manure value is through laboratory analysis. The minimum analysis should include percent dry matter, ammonium nitrogen (NH_4^+), total nitrogen (NH_4^+ + organic N), phosphorus (P or P_2O_5), and potassium (K or K_2O). Convert P_2O_5 values to elemental P by multiplying by 0.44, and convert K_2O to elemental K by multiplying by 0.83. Your local Cooperative Extension agent can assist in properly sampling manure for testing. (Also see "Sampling and Testing" on page 6.) Once a reasonable estimate of nutrient concentration is established, less frequent testing is acceptable.

Estimate Nutrient Availability in Manure

The fertilizer replacement value of litter and manure depends on many variables. Estimates of nutrient availability should be derived for the region where the nutrients will be used. Ammoniacal N is subject to being lost to the atmosphere unless it is injected or plowed into the soil soon after application. The remaining organic N must be mineralized to an inorganic form before it becomes plant-available. The rate of mineralization varies and depends upon many soil and climatic factors. Ultimately, the total amount of N available from litter or manure will be equal to that expected from the ammoniacal N, plus the amount of mineralized N from the organic form. Contact Cooperative Extension representatives in your area for the decay factors that best suit your location, or use the residual factors shown in table 6-2 (page 40).

Select a Crop Rotation and Cultural Practices that Maximize Nutrient Harvesting

Assumptions used in making your nutrient management plan should include realistic soil productivity indices consistent with production goals. Likewise, crop rotations and soil conservation practices should be realistic for the conditions likely to be encountered. The goal should be to harvest as many of the nutrients applied to the crop acreage as possible and to remove them from the cropping system.

Table 6-1. Procedures and coefficients for calculating manure nutrient values

Nutrient availability

Equations:*

$$\text{Avail N} = (A \times \text{inorganic } N) + [R \times (\text{organic N})] + \text{residual}^*$$
$$= (A \times NH_4) + [R \times (\text{total } N - NH_4)] + (\text{residual factor}) \times (\text{total } N - NH_4)$$

$$\text{Avail } P_2O_5 = B \times \text{total } P_2O_5$$

$$\text{Avail } K_2O = C \times \text{total } K_2O$$

Where,

R is the mineralization coefficient for poultry, 0.60. (If other coefficients are recommended for your state or region, use those instead.)

Inorganic $N = NH_4$

A, B, and C are application availability coefficients from the following table:

Nutrient availability coefficients

Method of application	Availability coefficient	Semi-solid manure	Dry litter
Broadcast *with* Incorporation:			
Immediate	A	0.75	0.95
	B	1.00	1.00
	C	1.00	1.00
Incorporate after 2 days	A	0.65	0.90
	B	1.00	1.00
	C	1.00	1.00
Incorporate after 4 days	A	0.40	0.80
	B	1.00	1.00
	C	1.00	1.00
Incorporate after 7 days or NO incorporation	A	0.25	0.75
	B	1.00	1.00
	C	1.00	1.00

NOTE: Some states have slightly different methods for computing nutrient availability and residual carryover. Check with appropriate state agencies for clarification.

- If manure analysis is reported as total N only, use the following ratios to distinguish between organic and inorganic N:

  Broiler litter: inorganic $N = 40\% \times$ total N
  organic $N = 60\% \times$ total N

  Turkey litter: inorganic $N = 30\% \times$ total N
  organic $N = 70\% \times$ total N

- Residual N is based on historical frequency of field manure application as follows:
  - Field rarely received manure in past (0 to 1 years in last 5 years): Residual factor = 0
  - Field frequently received manure applications (2 to 3 years out of 5 years): Residual factor = 0.10
  - Field continuously received manure (4 to 5 years out of 5 years): Residual factor = 0.20

General values for nitrogen mineralized from soil organic matter (SOM) are 40 pounds per acre per year for each 1% SOM. Nitrogen contributed from precipitation varies according to locality but may range up to 26 pounds per acre per year. Legumes can contribute 30 to 150 pounds of N per acre per year (see table 6-2, page 40). Additions from irrigation water can be estimated on a pounds-per-acre-inch basis by multiplying the N concentration in parts per million (PPM) by 0.227.

Test Soil to Determine Crop Nutrient Requirements

Maintain a good soil-testing program to monitor the nutrient status of fields and to determine additional nutrient requirements. Due to seasonal biological activity and mobility, soil N is not reliably predicted from soil testing, since testing will not accurately reflect the availability of N when it is most important to the crop. The lack of relationship between a preplant soil test and the N needs of the crop is due to plant-available N gains from mineralization and losses of available N through leaching and denitrification. This is of particular concern when applying litter and manure, which contain a large proportion of N in the organic form.

Advances in soil and plant N testing have provided new tools that enable management of litter- and manure-amended soils in a more environmentally sound manner. Perhaps the most promising test is the presidedress soil nitrate test (PSNT). The PSNT is based on sampling of the surface 1 foot of soil after the soil warms and the crop is growing. The amount of nitrate (NO_3) in the soil sample represents the plant-available N that will mineralize from soil organic matter. Thus, sidedress N fertilizer recommendations can be modified, depending on the level of NO_3 found in the soil.

PSNT procedures (for corn) are as follows (Evanylo and Alley, 1996):

- Conduct the test only on fields that have received no more N than a starter fertilizer application (25 to 30 pounds per acre). Fields that have received manure can and should be tested before making any supplemental N fertilizer applications at sidedress rates.
- Take soil samples at a corn height of 10 to 15 inches at the whorl, not with an upper leaf extended.
- Sample soil by taking ten to twenty cores across the field to a depth of 12 inches, if possible, or as deep as pos-

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sible. Sample between rows to avoid starter fertilizer bands and areas where roots have depleted soil N.

- Combine, mix, crumble, and dry samples as quickly as possible by spreading the mixed soil in a thin layer on newspaper in a warm place. Samples can also be dried in an oven at low heat (200 to 225°F) or in a microwave for 5 to 8 minutes at the high power setting.
- Use a reliable field test kit to determine soil NO_3 concentration. Check with your state Cooperative Extension personnel or land grant university. All field kits must be carefully calibrated and maintained in order to obtain reliable results.

When the soil NO_3 level has been determined, the guidelines shown in table 6-3 may be used.

Table 6-3 is provided to aid in understanding the use of the PSNT. Soil fertilization recommendations should not only incorporate results of the PSNT, but also include experience and understanding of the roles of soil properties and management practices in influencing N availability to crops.

Table 6-2. Nitrogen credit from legume residues

[illegible]	[illegible]	[illegible]	[illegible]
Alfalfa	50–75	Good (> 4 tons/acre)	90
	25–49	Fair (3–4 tons/acre)	70
	< 25	Poor (< 2 tons/acre)	50
Red clover	> 50	Good (> 3 tons/acre)	80
	25–49	Fair (2–3 tons/acre)	60
	< 25	Poor (< 2 tons/acre)	40
Hairy vetch	80–100	Good	100
	50–79	Fair	75
	< 50	Poor	50
Peanuts			45
Soybeans			½ pound N/bushel yield

Table 6-3. Nitrogen application rate guidelines based on pre-sidedress soil nitrate test (PSNT) results

NO_3 concentration	N rate recommendation [illegible]
< 11 ppm	Apply full rate of sidedress N that is needed for the realistic yield goal for the particular soil.
11–20 ppm	Possibly reduce the normal sidedress N application by 25–50%. This zone is uncertain, and decisions must be made on a site-by-site basis and should take into account previous field history, organic N additions, and management practices.
> 20 ppm	No sidedress N is needed.

NOTE: This table is provided to aid in understanding the use of the PSNT. Soil fertilization recommendations should not only incorporate results of the PSNT, but also include experience and understanding of the roles of soil properties and management practices in influencing N availability to crops.

Conduct a Hydrologic and Seasonal Evaluation

Evaluate the sensitivity and risk level of individual fields to leaching, runoff, flooding, and erosion. Make note of environmentally sensitive features such as sinkholes, wells, springs, streams, or other conditions that may have an impact on water quality. Determine the most suitable months for applying manure and fertilizer to reduce the nutrient loss potential, then apply nutrients as close as practical to crop uptake periods. Avoid fall or winter unless cover crops are used.

Determine Storage Requirement

Direct movement of litter from house to field will minimize handling costs and, if synchronized with a cropping plan, will usually allow more efficient utilization of manure nitrogen. Many producers, however, may not have enough land to utilize all litter properly or be able to coordinate house clean-out with times that litter can be directly spread. In some houses, only caked manure or crusts are removed between flocks, or cleaning of houses may not coincide with available open cropland or with proper field conditions that permit operation of equipment or desirable nutrient uptake. Storage should then be provided until conditions are suitable for spreading or until litter can be picked up for use by others as fertilizer, compost media, or animal feed. See chapter 4 for a discussion of storage options.

Manage Fertilizer

Commercial fertilizer should be used to supplement additional crop requirements when litter and manure, by themselves, will not meet crop needs. Apply fertilizer at a rate and by a method of placement that is consistent with efficient nutrient recovery.

Practice Good Soil and Water Conservation

Follow good soil and water conservation practices to minimize erosion and runoff. Steep slopes should be avoided, especially during winter. Slopes greater than 12 to 15% should be avoided for manure and litter application. If manure or litter must be applied on floodplains, incorporation or injection should be practiced to minimize nutrient and organic matter losses should flooding occur. Assistance is available from the Natural Resources Conservation Service for developing farm conservation measures. Voluntary nutrient management plans are being implemented in many states, and some states require plans as part of a permitting program.

Do Not Overfeed or Overfertilize

Overfeeding and overfertilizing are costly and environmentally unsound. Adjust and calibrate feeding equipment to minimize wasted feed. Calibrate manure and fertilizer spreading equipment regularly so that nutrients are applied uniformly and at the appropriate rate (see chapter 7). Schedule applications so nutrients will be used by growing crops and not lost to the environment. In fields where manure is applied intensively over a long period of time, there may be concerns about buildup of heavy metals such as copper and zinc in soils.

Nutrient Availability and Recovery

Nitrogen (N) is the most difficult nutrient in litter to manage. It exists in both the organic and mineral form. The mineral portion is mainly present as uric acid and urea, and in litter and manure analyses is referred to as ammonium N (NH_4^+). Decomposition of uric acid begins when it is excreted. Urea is converted to ammonium carbonate, an unstable salt, in a very short period of time following application and decomposes to ammonia gas (NH_3), carbon dioxide, and water. Decomposition will result in loss of up to 75% of the mineral portion of the N within seven days after spreading if manure is not soil-incorporated. The actual portion of mineral N lost is determined by the time elapsed between spreading and incorporation. The decision to incorporate manure will depend on factors such as the cropping system, cost of incorporation, cost of nitrogen, erosion hazard created by the tillage, and availability of equipment.

The organic N fraction gradually becomes available for crop uptake as the manure is decomposed. Approximately 60% of the organic N in poultry manure and litter at the time of application is released during the first year following application. The remainder is released through a decay series with passing time. For practical purposes, nutrient planners credit a portion of the remaining "residual" N based on previous organic waste application history. Fields that have rarely received manure during the past 5 years are given no residual credit. Fields that frequently received manure, perhaps 2 or 3 years out of the past 5 years, are allocated 10% of the normal organic N loading as residual credit. And fields that received continuous application for the previous 5 years are given residual credit of 20% of normal organic loading. Therefore, the total amount of nitrogen available from manure applications is the sum of that available from applications being made at a given time plus that available from expected residual N. For more information about calculating available nitrogen, see table 6-1 (page 39).

Litter applications should be planned when crop interval and soil and climatic conditions are suitable. Applying litter near the planting date on soils prone to leaching will reduce nitrogen losses. But lowered germination and reduced seedling growth could occur if planting is done immediately after heavy applications, especially since high ammonium or inorganic salt levels may be present in litter.

Land Application Program

A well-planned land application program is based on the nutrient requirements of the crop. However, the ratio of N to P to K in litter almost never matches the ratio of the amount of these nutrients needed by crops. Therefore, complete utilization is rarely accomplished. If litter is applied at rates that will supply all the N needed by the crop, P and K applications greater than those needed by the crop may occur. This will not be serious in the short run, because soils have the capacity to adsorb the extra P and K. However, as these nutrients accumulate, problems may develop. For example, where crops will be used for ruminant livestock feed, and K levels in the ration reach 5% due to excessive K applications, tetany problems may develop. Plant tissue analyses and soil tests will help identify these potential problems. If soil tests or tissue analyses indicate P and K levels are in the medium to high range, it might be wise to shift to a phosphorus or potassium basis for determining litter applications.

The following discussion, along with the worksheets and examples that follow, shows how to match litter or manure application rates to crop production needs for specific farm conditions.

Nutrients Collected

The amount of N, P, and K originally deposited in the litter or manure is not likely to be the amount eventually applied to the land. Nutrient losses occur during handling and storage—as liquid losses; ammonia volatilization; or leaching and erosion of N, P, or K. Therefore, to account for losses, litter samples should be taken for laboratory analysis at the time of land spreading. Analysis of a series of samples will help establish a good estimate of litter nutrient content on your farm. Periodic additional sampling will help maintain accurate estimates of litter nutrient content.

Determine the litter density as follows:

1. Fill a pail with water and weigh it in pounds.
2. Refill the pail with litter, tamp to approximate the stack compactness, and reweigh it.
3. Calculate the pail volume: volume of pail (cubic feet) = weight of water (pounds) ÷ 62.4 pounds per cubic foot of water.
4. Calculate the litter density: litter density (pounds per cubic foot) = weight of litter (pounds) ÷ volume of pail (cubic feet).

Estimate the amount of litter and nutrients over a given time, as follows:

1. Cubic feet of litter = storage length (feet) x storage width (feet) x storage depth (feet)
2. Tons of litter = cubic feet of litter x litter density (pounds per cubic foot) ÷ 2,000 pounds per ton
3. Total pounds of nutrient = tons of litter x pounds of nutrient per ton of litter (from litter analysis)

EXAMPLE: A litter storage structure measuring 30 feet by 85 feet with an average litter depth of 5 feet contains 12,750 cubic feet of litter. Using the pail method above, the density of the litter is determined to be 40 pounds per cubic foot. Analysis of the litter showed 75% dry matter with 66 pounds of total N, 15 pounds of NH_4, 63 pounds of P_2O_5, and 30 pounds of K_2O per ton. Calculating as described above, the storage would contain 255 tons of litter containing 16,830 pounds of total N; 3,825 pounds of NH_4; 16,065 pounds of P_2O_5; and 7,650 pounds of K_2O.

Nutrient Loss

The total nutrient content of litter cannot be substituted for that in commercial fertilizer on a pound-for-pound basis. This is because some of the litter and manure nutrients are not as readily available, and they cannot be as efficiently applied as those in fertilizer. Therefore, you must calculate the litter and manure N that can replace fertilizer N.

Once you have estimated the nutrient content of your litter and manure, consideration must be given to the losses involved during land application. These are primarily the volatilization of the ammonium N; for broiler litter, this amounts to about 25% for broadcast application (see table 6-1, page 39). If litter is incorporated during the first 24 hours after application, losses are reduced to 10% or less.

Following the example in worksheet I (page 43) will help you understand calculation of litter value. Greatest accuracy in determining nutrient content will be obtained from litter sample test reports. Otherwise, assume the values given in tables 1-2, 1-4, 1-5, and 1-8. Be sure to allow for residual N carryover from previous years' applications and from nitrogen-fixing crops. Also, note that losses of N, P_2O_5, and K_2O due to the method of application must be considered (see table 6-1, page 39). Losses of N are due primarily to ammonia volatilization. Although losses of P_2O_5 and K_2O may occur due to rainfall erosion and runoff, these nutrients are not volatilized and are generally totally allocated for nutrient management purposes.

Other Additions to the Nitrogen Pool

The majority of nutrient contributions are from commercial fertilizers, litter/manure, and residual mineralization of organic N. However, other sources must also be considered to avoid overapplication of N. Sources of additional N are:

- mineralization of soil organic matter,
- atmospheric deposition from precipitation,
- contributions from irrigation water,
- credits from legumes, and
- crop residue mineralization.

The example given in this discussion (worksheets I and II, pages 43 and 44) does not include additions from any of the above sources. However, planners should check to see if these sources may contribute significantly to the overall nutrient budget. If N will be contributed, these additions should be subtracted from the estimated crop requirement.

Determining Rate of Application

Some planning and pencil work are required to find the application rate that best fits a particular cropping sequence. Worksheet II (page 44) provides a simple outline and example of the process to help you determine: (1) the nutrient requirements of the crop to be grown, (2) litter nutrient content, (3) litter application rate needed to supply the highest priority nutrient, and (4) the amount of commercial fertilizer needed in addition to the applied litter.

Determine from your local Cooperative Extension agent or other sources the amount of N required for the crop to be grown without litter. Then use worksheet II to determine how much N must be added by a combination of commercial fertilizer and litter.

Worksheet I: Estimating the Amount of Nitrogen Available for Crop Production

EXAMPLE

A litter sample was taken from a storage structure and analyzed. The following calculations show how to estimate the amount of nitrogen (N) that will be available during the growing season from the planned litter application and from previous applications. Assume that 3 tons per acre, having an organic N content of 49 pounds per ton, were applied in each of the past 3 years.

CALCULATIONS

A. Insert the percentage of dry matter and values for nutrients from the analysis, in pounds per ton. (Some laboratories may report N results under the heading "nitrogen" and "ammonium N." The larger of the two numbers is total N. Organic N is the difference between total N and ammonium N. If test results are not available, use values from table 1-2, 1-4, 1-5, or 1-8 in chapter 1.)

	Example	*Your form*
Dry matter	72%	
Total N	64 lbs/ton	
Ammonium N	15 lbs/ton	
Organic N	49 lbs/ton	
P_2O_5	63 lbs/ton	
K_2O	30 lbs/ton	

B. Determine the availability of N during the first year. Available N = pounds of ammonium N or organic N (from item A) x percentage of availability (from table 6-1, page 39).

	Method of application	Quantity available from: Ammonium (lbs x %)		Organic (lbs x %)		Available N
Example	Broadcast	15 x 0.75	+	49 x 0.60	=	40.7 lbs/ton
	Broadcast w/immediate incorporation	15 x 0.95	+	49 x 0.60	=	43.7 lbs/ton
Your form			+		=	

C. Determine the availability of N from previous applications. (Omit if litter or manure was not applied during the past 5 years.) From table 6-1 (page 39), the residual factor for the previous 3 years of application is 0.10. Available N per acre = application rate from previous records in tons or 1,000s of gallons x pounds of organic N per ton or per 1,000 gallons x residual factor (from table 6-1).

Residual N = 3 tons/acre x 49 lbs/ton organic N x 0.10 = 14.7 lbs/acre residual N.

D. Determine the amounts of P_2O_5 and K_2O applied.

	Time of application	P_2O_5	K_2O
Example	Broadcast	63 x 1.0 = 63 lbs/ton	30 x 1.0 = 30 lbs/ton
	Broadcast with immediate cultivation	63 x 1.0 = 63 lbs/ton	30 x 1.0 = 30 lbs/ton
Your form			

Worksheet II: Estimating a Rate of Application

EXAMPLE

A grower will apply litter in early spring but not incorporate. From the litter analysis and nitrogen (N) calculations in worksheet I, determine the rate of application to meet the N requirement, the amount of P_2O_5 and K_2O added, and the amount of commercial fertilizer needed.

CALCULATIONS

	Example	*Your farm*
A. Determine the nutrient needs of the crop.		
1. Crop to be grown.	Combination corn/rye silage	______
2. Nutrient requirements from university recommendations.	N = 220 lbs/acre	______
	P_2O_5 = 125 lbs/acre	______
	K_2O = 160 lbs/acre	______
B. Determine the nutrient value of manure. Express as pounds per ton for a nonliquid system or pounds per 1,000 gallons for a liquid system.		
1. Available N from item 3 in worksheet I.	N = 40.7 lbs/ton	______
2. P_2O_5 from recent analysis (if test results not available, use table 1-2, 1-4, 1-5, or 1-6 in chapter 1).	P_2O_5 = 63 lbs/ton	______
3. K_2O from recent analysis (if test results not available, use table 1-2, 1-4, 1-5, or 1-6 in chapter 1).	K_2O = 30 lbs/ton	______
C. Determine the rate of application.		
1. Select nutrient having the highest priority.*	N	______
a. Amount to be supplied by manure. Express as pounds needed in item A.2 minus amount of fertilizer applied.	= 220 lbs/acre	______
b. If N, subtract residual N availability from item C in worksheet I.	220 − 14.7 lbs residual = 205.3	______
2. Rate of manure needed to supply highest priority nutrient (item C.1b divided by item B.1). Express in tons per acre for a nonliquid system or as 1,000s of gallons per acre for a liquid system.	205.3 lbs/acre ÷ 40.7 lbs/ton = 5.0 tons/acre	______
3. Pounds of N, P_2O_5, and K_2O applied per acre with manure.		
a. N value from item B.1 times manure rate from item C.2 plus residual N availability from item C in worksheet I.	N = 218.2 lbs/acre	______
b. P_2O_5 value from item B.2 times manure rate from item C.2.	P_2O_5 = 315 lbs/acre	______
c. K_2O value from item B.3 times manure rate from item C.2.	K_2O = 150 lbs/acre	______
D. Determine the amount of commercial fertilizer needed (difference between item A.2 and item C.3).	N = 0; P_2O_5 = 0; K_2O = 0 lbs/acre	______

* Future requirements may favor calculations based on phosphorus as the limiting nutrient.

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CHAPTER 7

Application Equipment

Equipment selection for handling and spreading solid and liquid manure depends on the consistency of the material, the type and amount of bedding or water added, the crop and field conditions, the timing of spreading events, and the haul distance to the field.

Solid and Semi-Solid Handling Equipment

Solid materials such as litter are usually removed from a production facility with a bucket loader (tractor-mounted or skid-steer), a scraper (box or blade), or a cruster.

Bucket Loaders, Scrapers, and Rototillers

Litter with surface cake might need to be rototilled before complete house clean-out. Tractor PTO-driven, three-point-hitch-mounted rototillers break the cake apart and mix it for easier spreading and more uniform field distribution. Tractor-drawn box scrapers are used to move the litter to loading points within the production houses (figure 7-1).

Bucket loaders with forks (tines) are often used to remove cake from poultry houses (figure 7-2). Bucket loaders are also used to move solid litter and semi-solid layer manure from collection points, stockpiles, or storage/settling basins to spreaders or trucks. The loader may be attached to a skid-steer vehicle or the front end of a farm tractor. The lifting capacity varies from about 400 pounds for a loader attached to a large garden tractor to several thousand pounds for one fitted to a 100-horsepower tractor. Breakaway capacity—the ability to tear manure from a pile—is several hundred pounds greater than lift capacity. The capacity of the loader depends on the size of the hydraulic system and the weight of the tractor. Hydraulic system components need to be well maintained to supply an operating pressure from 1,000 pounds per square inch for smaller systems to over 2,000 pounds per square inch for larger units.

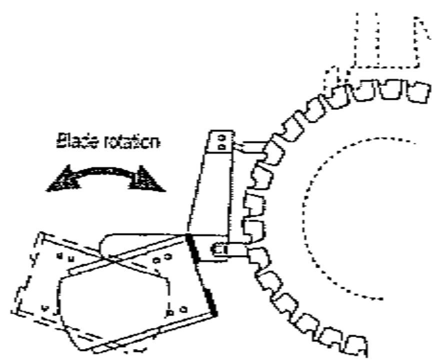

Figure 7-1. Tractor-drawn box scraper
Source: Natural Resources Conservation Service

A loader usually comes with a bucket designed for the material to be handled. A smaller bucket would be needed for dense, heavier materials like soil, sand, grit, or semi-solid manure. A larger bucket is better for bulky, lightweight materials such as sawdust and production facility litter. The loader should be easily attached and detached from a tractor that must be used for other purposes. Counterweights may need to be added to the rear of the tractor to use the bucket to capacity. Use of oversize tires on the front of the tractor can give more stability and better maneuverability.

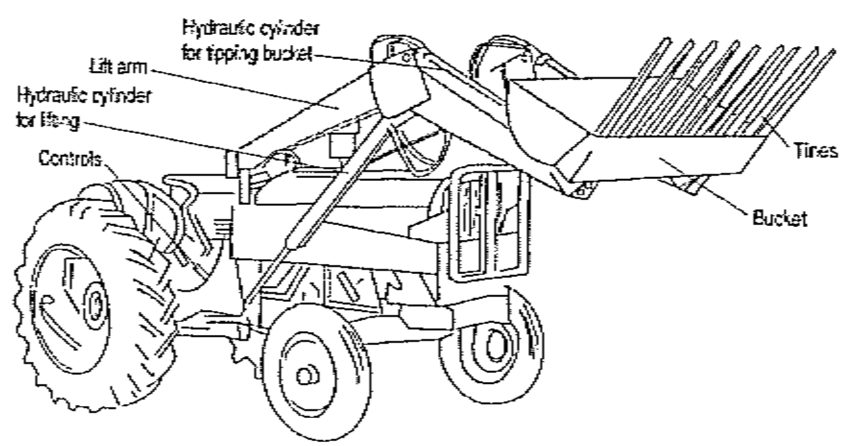

Figure 7-2. Bucket loader with tines
Source: *Fertilizer and Manure Application Equipment*, NRAES-57

Crusters/Housekeepers

Cake manure is sometimes removed with a tractor-drawn cruster (figure 7-3). The cruster requires an 18- to 60-horsepower tractor. It picks up the surface cake manure and reconditions the remaining litter for the next flock. A blade at the front of the machine can be set for the desired depth of litter to be removed, usually 1 to 2 inches. The material is lifted into hydraulically driven rotating tines that break apart the cake and move it onto an inclined conveyor screen. The fine litter particles are separated, fall through the screen, and remain in the house. The cake is deposited into a trailer with a capacity ranging from 3.5 to 5.5 cubic yards.

Crusters can be equipped with a rear spreader assembly to field spread the litter directly from the house. An automatic self-dumping trailer allows the collected material to be stockpiled. Crusters with the spreader assembly can also be used to spread new litter in the production houses.

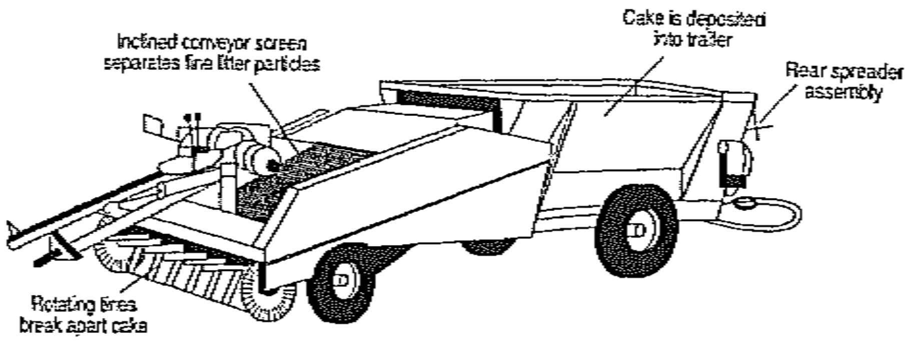

Figure 7-3. Tractor-drawn cruster

Source: *Agricultural Waste Management Field Handbook*, Natural Resources Conservation Service

Box-Type Manure Spreaders

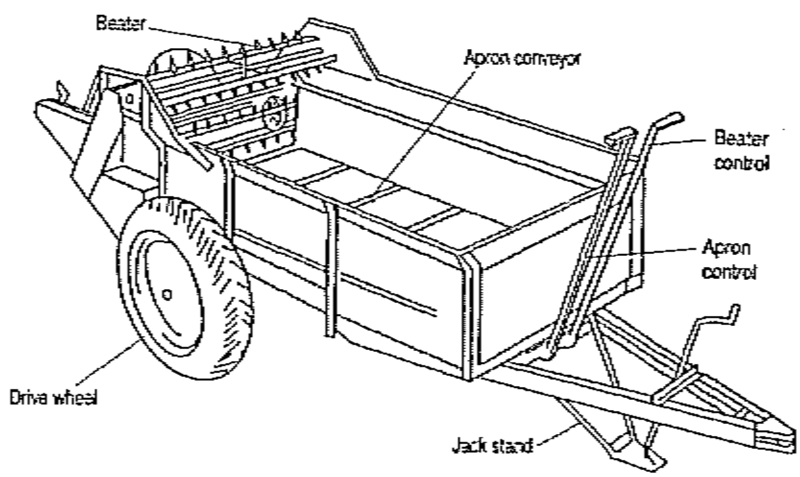

Figure 7-4. Ground-driven box-type manure spreader

Source: *Fertilizer and Manure Application Equipment*, NRAES–57

Box-type manure spreaders may be either tractor-drawn or truck-mounted and can handle either solid or semi-solid material (figure 7-4). The rotating rear beaters help to break up large clumps of manure such as litter cake and do a better job of evenly distributing semi-solid or heavier, wetter manures than drier, lightweight litter. The quality of the steel or treated wood used in the box construction is important for resistance to corrosion and rotting due to manure acids.

The capacity of a box spreader is usually designated by the manufacturer in cubic feet of the box, either level full with the top of the box or heaped above the top. Box spreaders are available in capacities ranging from 30 to 400 cubic feet. They require tractor sizes from 30 to 160 horsepower. Spread time or time to empty the spreader ranges from 1 to 3 minutes.

Depending on the amount of water and bedding, solid litter and semi-solid manures have different densities. An on-farm test can determine the density and help to estimate the weight on a loaded spreader. Weigh an empty 5-gallon bucket. Fill the bucket level full with material to be spread. Do not pack the material in the bucket, but ensure that it settles to approximate a loaded spreader. Weigh the bucket full and then subtract the empty weight. Multiply the weight of the contents by 1.5 to obtain pounds per cubic foot of the litter. Multiply this value by the cubic feet capacity of the spreader and divide by 2,000 to find the tons of material in a spreader load:

spreader load (tons) =

$$\frac{\text{manure weight (pounds)} \times 1.5 \times \text{spreader capacity (cubic feet)}}{2{,}000}$$

The power needed to drive the apron chain and beaters comes from either the spreader wheels or the tractor PTO. In PTO models, power is transmitted through shafts, chains, and sprockets to a gearbox. From there, chain drives transmit power to the beaters and apron. A PTO-driven machine can unload while standing still for stockpile formation or while moving very slowly for compost windrow formation.

Ground-driven machines depend on wheel friction against the ground to power the machine. Tires should be mounted with tread lugs oriented in the opposite direction from those on the towing tractor tires. Improper wheel mounting and lack of good traction on the spreader may cause poor performance and hamper spreading efficiency.

The apron conveyor consists of chains on each side of the bottom of the box connected by steel slats. As the conveyor operates, the load is slowly moved toward the back of the box and into the beaters. The feed rate of the conveyor is adjustable and allows for different manure application rates. A cam drive and ratchet are often used to make the adjustment.

Some spreaders do not have adjustments low enough to allow for light application rates of nutrient-rich materials like house litter. Many conventional box spreaders can be modified to spread at the lower rates required for most poultry litter. Some dealers supply sprocket replacement kits that can be added to spreaders to allow for a wider range of application rates.

At the end of the box, the manure is fed into beaters to shred any clumps. Their operating speed is controlled by a lever at the front of the machine convenient to the tractor operator. When purchasing spreading equipment, be sure application can be easily and effectively adjusted for the desired application rate.

Some manufacturers place an auger-type device called a "widespread" behind the beaters to help spread the manure in a swath wider than the machine (figure 7-5). Semi-solid manure can be handled by a box spreader if it has an endgate installed to contain the manure and fluids until reaching the field. The gate can be adjusted to control the spreading rate. A curved pan underneath the beaters and auger can also more evenly spread fluids that might otherwise drain directly from the box when the gate is raised.

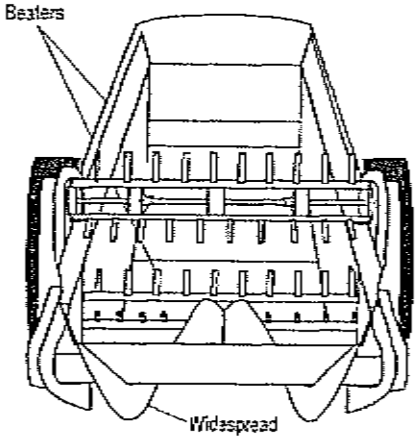

Figure 7-5. Manure spreader with widespread
Source: *Fertilizer and Manure Application Equipment*, NRAES-57

It is best to load the spreader box starting at the front, taking care to heap but not overload manure. The manure moves more easily with this loading pattern and spreads more uniformly. For best results, the spreader should be operated at speeds below 4 miles per hour. The spreader will last longer if it is washed and maintained after each use and stored under cover.

Side-Delivery Flail Spreader

The flail spreader consists of a liquid-tight tank supported horizontally on a tractor-drawn trailer (figure 7-6). The top of the tank is open for loading, but it is covered by a hydraulically movable lid to prevent manure from being thrown high in the air during unloading.

A flail spreader may be the best choice for small-farm operators who handle manures with a wide range of consistencies. This type of spreader will handle solid, semi-solid, and slurry manure but is best suited for the wetter manures. The spreading action is from a powered horizontal shaft located through the center of the tank. Flail chains with steel tips rotate and throw the manure out by centrifugal force. A uniform spreading width of up to 20 feet can be achieved.

The shaft is powered from a 540-RPM or 1,000-RPM tractor PTO speed. A gearbox or sprocket-and-chain drive is used to reduce the shaft speed to get the proper unloading rate.

Available models range from 400 gallons requiring a 30-horsepower tractor to 1,400 gallons needing a 110-horsepower tractor. The flail spreader requires moderate maintenance and operates best when it is cleaned and maintained after each use. A used machine should be checked for a corroded tank, worn flails, or cracked tires.

Side-Delivery Expeller Spreader

Expeller spreaders offer the most versatility in uniformly handling and spreading a wide range of materials with different consistencies, such as dry litter, semi-solid scraped manure, lagoon sludges and grit, and low-solids slurries. They can be either tractor-drawn or truck-mounted. Capacities range from 900 gallons requiring a minimum of 50 horsepower to 3,800 gallons needing at least 140 horsepower. The spreader is constructed of high-strength, corrosion-resistant steel.

The V-hopper tank sits on either a single- or tandem-axle chassis. The top of the tank has a low profile if loading height is a problem, or it can have bolt-on sidewall extensions for extra capacity.

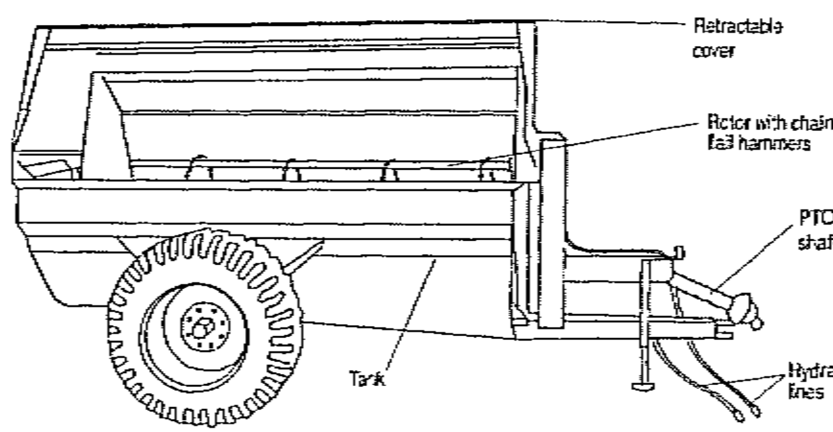

Figure 7-6. Flail spreader
Source: *Fertilizer and Manure Application Equipment*, NRAES-57

A PTO-driven auger 22 to 30 inches in diameter located near the bottom of the tank moves the material toward the expellers at the front. Double extension coil springs hold the auger down but leave it free to float over rocks or other foreign material, thus reducing damage. The auger may be lifted hydraulically to break up bridged material in the tank, or it may be powered down into denser, settled material through double-acting hydraulic cylinders.

Expellers are located on one side at the bottom of the tank and near the front of the spreader. A tank sliding door ranging from 20 to 46 inches wide can be hydraulically opened and controlled to vary the rate of application. Rotating offset paddles or free-swinging hammers on a reel approximately 18 inches in diameter engage the manure with a slicing motion, expelling it in a uniform pattern in swaths up to 40 feet wide. PTO power is delivered to the expeller reel through a chain or belt-drive transmission.

Spinner Spreader

Spinner spreaders are similar in appearance and operating principle to lime spreaders. They are most often used with dry, lightweight litter, since they provide the best spread pattern for this type of material. They may be tractor-drawn but are most often V-hopper tanks mounted on either a single- or tandem-axle truck chassis with capacities ranging up to 500 cubic feet.

At the bottom of the hopper tank is a 30-inch-wide channel with a bar-flite conveyor that moves the litter to the rear of the spreader. An adjustable endgate can be opened to adjust the rate of application. When open, the conveyor delivers the litter onto twin opposed-direction metal spinners. These spinners range from 18 to 26 inches in diameter and rotate at speeds of about 500 RPM. Spinners rotating too fast seriously disrupt the spread pattern. Each spinner also has three to four vanes on the surface to help propel the litter particles. An adjustable splitter or flow divider is located just above the spinners to evenly divide the litter from the conveyor to the two spinners. The spinner assembly may also be adjusted forward or backward to change the point at which the litter falls onto the spinners. The desirable drop point is approximately one-third of the spinner radius to the front or the rear of its center. The effective spread width ranges from 26 to 32 feet. Some of the heavier particles may be propelled up to 50 feet.

Some spinner spreaders have conveyors that are mechanically driven from the truck wheels, but most operate both the conveyor and the spinners hydraulically. Some truck spreaders have the entire spreader tank mounted on load cells such that the weight of material loaded or being discharged can be instantaneously and continuously monitored.

Calibration of Solid Spreaders

Calibration defines the combination of equipment settings and travel speed needed to apply manure, litter, or wastewater at a desired rate and to ensure uniform application. The following method can be used to determine the application rate of a manure spreader without measuring the entire area of application or knowing the spreader capacity.

First, weigh an empty, dry sheet of plastic approximately 100 square feet in surface area in a bucket or basket. Determine the actual area of the sheet by multiplying the width by the length to get square feet. Then spread the sheet on the ground and pin or weight the corners and edges. Then operate the spreader over the plastic sheet at normal application settings and operating speed starting at least 50 feet away from the sheet. Weigh the sheet and the collected manure. Subtract the weight of the empty sheet to determine the weight of the spread manure. Multiply the pounds of manure collected on the sheet by 21.78, and then divide by the area of the sheet to obtain the manure application rate in tons per acre:

$$\text{application rate (tons/acre)} = \frac{\text{manure collected on sheet (pounds)} \times 21.78}{\text{area of sheet (square feet)}}$$

Repeat the process at least three times to get a reliable average application rate. If a target application rate is desired, follow the above procedure, adjusting spreader settings and travel speeds until the desired application rate is obtained.

To determine the uniformity of spread and the amount of overlap needed, place a line of small pans or trays equally spaced 4 feet apart on centers across the spreader path. The pans should be a minimum of 12 inches by 12 inches, or 15 inches in diameter, no more than 24 inches by 24 inches, and 2 to 4 inches deep. Make one spreading pass, centering the application pattern directly over the center pan; for rear discharging spreaders, this will require driving directly over the center pan. Weigh the contents caught in each pan or pour the contents into equally sized glass cylinders or clear plastic tubes, placed in the same order as the pans, and compare the amount in each. The effective spread width can be found by locating the point on either side of the path center where the manure contents caught in the containers is half of what it is in the center. The distance between these points is the effective spread width. The outer fringes of the coverage area beyond these points should be overlapped on the next path to ensure a uniform rate over the entire field. When viewing across the cylinders or tubes, "flat-top," "pyramid," or "oval" patterns are most desirable and give the most uniform rate of application. "M," "W," "steeple," or "lop-sided" patterns are not satisfactory, and spreader adjustments should be made until a satisfactory pattern can be obtained.

Liquid Handling Equipment

NOTE: This section summarizes liquid handling equipment for poultry operations. For more detailed information about liquid manure handling equipment and applica-

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tion systems, see *Liquid Manure Applications Systems Design Manual*, NRAES–89, in "Suggested Readings" on page 63.

Slurry/Sludge Pumps

Solids in liquid manure slurries separate during storage in tanks and earthen basins. This material must be agitated and mixed before removal. Mixed slurries typically have up to 12% total solids, and lagoon bottom sludges have up to 17% total solids. Specialized agitation and pumping equipment are needed to handle materials this thick.

Tractor-PTO-propeller mixers provide the most vigorous and effective agitation of manure slurries (figure 7-7). These three-point-hitch-mounted mixers consist of a power shaft connected to a 20- to 28-inch-diameter open propeller requiring 60 to 120 horsepower for agitation. Since these mixers only provide the capability to agitate, the preferred choice might be a PTO chopper-agitator pump to both mix and pump manure slurries.

Vertical shaft cantilevered pumps with enclosed impellers located near the bottom of the tank are generally used in a storage tank or in conjunction with a vertical dock at an earthen basin. The impeller has a cutter blade operating against a shear plate to break up clumps of materials. Open-pit, trailer-mounted PTO pumps capable of agitating and pumping in a slanting position are most suitable for earthen storage basins with sloping banks. Most of these pumps have an agitation/pumping rate ranging from 2,400 to more than 10,000 gallons per minute at total dynamic pressure heads ranging up to 90 feet. Power requirements range from 60 to 160 horsepower. Tractors should be operated in level positions to avoid engine and drive train damage. A six-month accumulation of slurry should normally be agitated just before emptying and typically requires 4 to 12 hours for complete mixing. Most chopper-agitator pumps have an effective agitation radius of 40 to 80 feet. The addition of extraneous materials such as plastic wrappers, egg flats, and long-stemmed vegetation to manure storages should be avoided, since these materials readily clog pumps.

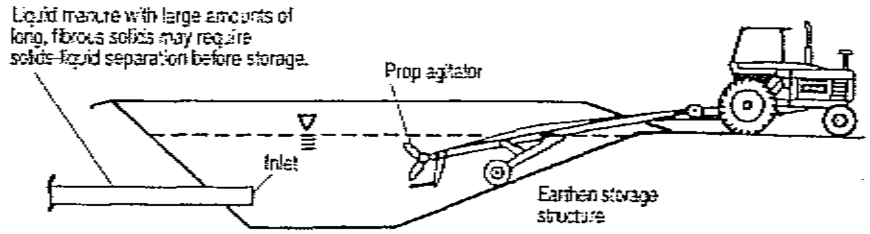

Figure 7-7. Agitation with a tractor-PTO-propeller mixer
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

Hydraulically operated impeller pumps, which can be located near the bottom of lagoons, are also used to lift sludge to a spreader or irrigation pump. These pumps will provide neither agitation nor enough pressure for irrigation.

Tank Spreaders

Liquid slurries and lagoon sludges are most often handled using enclosed tank spreaders with capacities ranging from 1,000 to 6,500 gallons; the typical size is about 3,000 gallons. A 3,000-gallon spreader can spread about three loads per hour with a 2,000-foot haul distance. Only about one-third of the time actually involves field manure spreading; loading and travel account for the remaining time.

Spreader tanks can be either trailer-mounted on a tractor-drawn walking beam tandem axle, or they can be truck-mounted (figure 7-8). Most trailer-mounted tankers are equipped with hydraulic surge brakes for operator safety. Truck-mounted tanks are more economical and less time-consuming for hauling distances greater than 1 mile. Larger-capacity tanks are also mounted on high-flotation, self-propelled applicators.

The horizontally mounted tank usually contains an agitating device, either an auger or pump, to keep solids in suspension. An opening at the top of the tank is used for filling, while a hydraulic gated opening at the rear bottom discharges the manure into a semi-enclosed spinner or fan for spreading. The spreading rate is controlled by the size of the opening and ranges from 550 to 1,000 gallons per minute, with an effective spread width of 15 to 25 feet. The spreading device (spinner or fan) is powered by shafts and driven from the PTO.

A top-loaded spreader must be filled with a liquid manure pump. Some manufacturers build a self-loading tank spreader. A PTO-driven vacuum/pressure reversing pump rated from 135 to 350 cubic feet per minute with 90% vacuum is mounted on the front of the spreader chassis. In the loading mode, the pump pulls a vacuum inside the tank that draws manure slurry in through a rear suction hose. In the spreading mode, the pump pressurizes the spreader tank and forces the contents through a rear valve onto a deflector plate. The tank is slower to load than a top-loaded spreader and does not provide storage agitation.

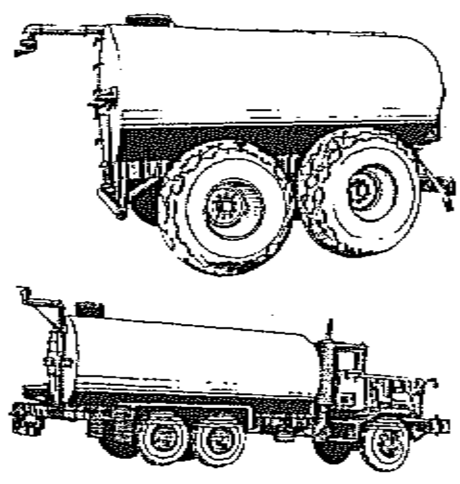

Figure 7-8. (Top) Trailer-mounted tandem axle liquid manure spreader; (Bottom) Truck-mounted liquid manure spreader
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

Liquid manure spreaders also provide the option of surface spreading the slurry or injecting it directly into the soil. Soil injection reduces odor potential and nitrogen loss. The rear-mounted enclosed impeller housing is connected by a 4- or 5-inch flexible hose to a slurry distribution header (figure 7-9). The distribution header is connected by 2-inch flexible hoses to each of two to five spring-loaded injector shanks mounted on a tool bar. The injectors may be mounted on the tractor three-point hitch or on the spreader frame. Locating the injectors behind the wheels is desirable, because the injector shanks break up the soil compaction in the upper layers behind the wheel tracks. Although injectors are optionally equipped with a fluted coulter to open a slit in front of the shank, they are not well-suited for sod ground. Injector points may be 2-inch narrow chisels, duck-foot shovels, or 10-inch-wide sweeps (which provide the best distribution).

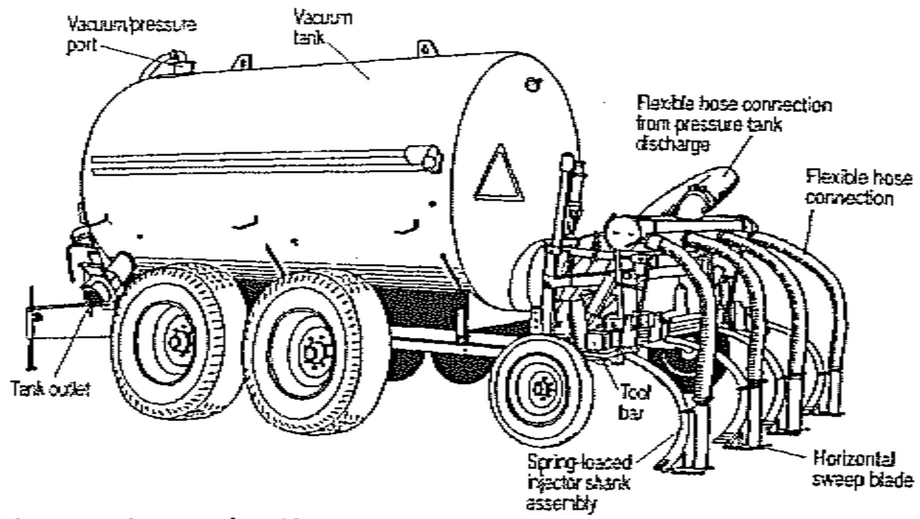

Figure 7-9. Vacuum tanker with injector assembly
Source: Liquid Manure Application Systems Design Manual, NRAES-89

Calibration of Liquid Spreaders

The application rate for a liquid manure spreader can be determined by knowing: 1) the capacity of the tank in gallons; 2) the distance the spreader travels to empty the tank; and 3) the path width over which the water is being spread. The path width can be paced off or measured with a tape. Determining the travel distance can be more difficult. One method is to measure and count the number of wheel rotations of one of the pieces of equipment used. Select a wheel on either the tractor or manure spreader, and measure the tire from one side to the other across the end of the axle; this should be the wheel diameter. Multiply the diameter by 3.14 to determine the distance the spreader will travel in one tire rotation. Tie a piece of rope around the tire, or mark a spot on the tire wall using a piece of duct tape. As the spreader moves through the field, count the number of times the rope comes to the top of the tire until the tank is empty. Multiply the number of wheel revolutions by the distance traveled in one revolution to determine the total distance traveled.

The waste application rate is approximately:

$$\text{application rate (gallons/acre)} = \frac{\text{tank capacity (gallons)}}{\text{travel distance (feet)} \times \text{spreading width (feet)}} \times 43{,}560 \text{ square feet/acre}$$

Solids Separators and Settling Basins

Lagoon management is eased by separating solids from raw or flushed manure prior to lagoon input. Removing grit and feathers from layer manure significantly reduces the lagoon solids buildup rate and associated pumping problems.

To recover a relatively dry by-product, vibrating screen, sloping stationary screen, extrusion, or belt-press mechanical separators are advantageous. Manure is either scraped or flushed to a sump to store 3 to 4 days' accumulation of manure and wastewater. A submersible or stationary bottom-impeller, agitator-lift pump mixes the manure into a slurry and pumps it to the separator, where liquids drain to a lagoon. Separated solids are dry enough to be handled by conventional materials handling equipment. Up to 30% of the total solids and 25% of the oxygen-demanding organics are removed with the solids.

A gravity settling basin may be a less costly way to remove 50% or more of the solids from liquid manure. Solids can be settled and filtered by a shallow basin (2 to 3 feet deep) with a concrete floor and walls and a porous dam or perforated pipe outlet (figure 7-10). The basin should allow access by a front-end loader to remove solids every 1 to 2 months. An alternative is an earthen settling basin for 6 to 12 months' storage of solids. The basin top width should be no more than 100 feet with a length-to-width ratio near 3:1 and a liquid depth of 8 to 10 feet. The basin contents should be thoroughly agitated and removed for land spreading either by liquid manure spreader or slurry irrigation. A third alternative consists of a large rectangular metallic or concrete settling tank with a 3:1 length-to-width ratio and an 8-foot liquid depth. Tank volume depends on a peak-flow wastewater detention time of 10 to 30 minutes. Most readily settleable solids in poultry manure settle in about 10 minutes, although some additional settling occurs for hours. Tank inlets and outlets are baffled and solids are removed by automated skimmers and scrapers.

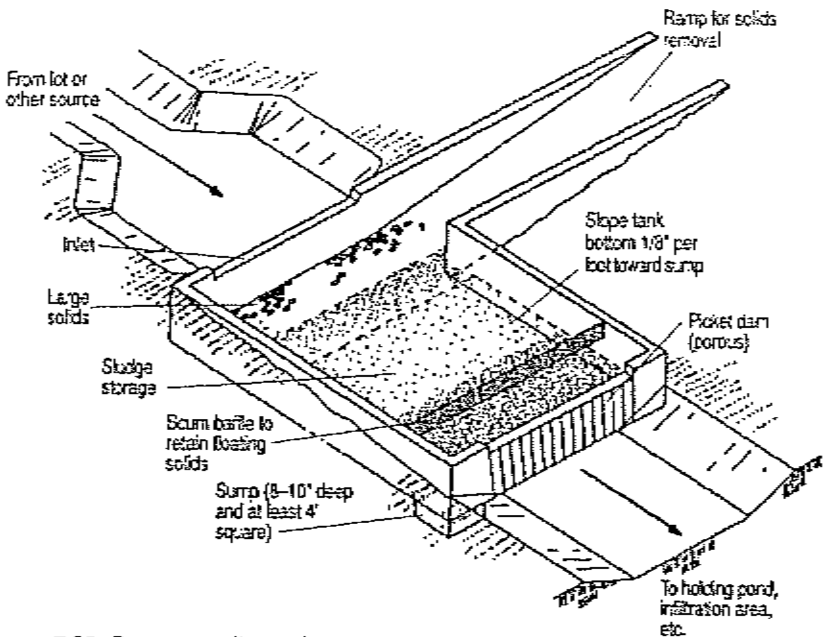

Figure 7-10. Concrete settling tank

Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

IRRIGATION SYSTEMS

Irrigation Pumps

For irrigating wastewater with solids contents under 4%, such as lagoon liquids, standard centrifugal pumps are recommended over specialized chopper pumps or cutter attachments. These pumps are most often driven by a PTO, direct drive internal combustion engines, or electric motors. Centrifugal pumps will not provide enough suction lift to remain primed with wastewaters or slurries with solids contents higher than 7%. In the case of slurries or sludges with solids contents higher that 7%, a solids-handling lift pump is needed to assist the irrigation pump. If a lagoon contains an appreciable amount of long-stemmed vegetation or large debris, this material should be removed and efforts made to prevent its recurrence. Pump power requirements for lagoon liquid are similar to those for water, provided the solids content is less than 4%.

The suction line and strainer should be floating in the lagoon such that the intake is about 18 inches below the liquid level to draw the most solids-free water. The pump should be located as far from the inlet drain to the lagoon as possible to avoid clogging by untreated manure solids.

Electric motors up to 7.5 horsepower, and in some locations up to 10 horsepower, can be installed on single-phase power lines without phase converters for three-phase service. Producers without three-phase service may be limited to using the smaller single-phase motors, or using direct-drive internal combustion engines or tractor PTO drives.

To compute the motor or engine horsepower required, the system flow capacity (in gallons per minute) and total dynamic head (TDH) have to be determined. Flow capacity is determined by multiplying the number of sprinklers operating at one time by the capacity of one sprinkler. The TDH includes the sprinkler pressure (in feet of water column; 1 pound per square inch = 2.31 feet), the lateral and main line pipe friction losses, and the elevation difference. Friction loss in the lateral line is determined from an irrigation slide rule or friction loss tables, and then divided by two. Main line friction loss is determined from an irrigation slide rule or from friction loss tables. The elevation difference is the vertical distance between the lagoon liquid surface and the highest sprinkler in the field. Pumps should be capable of delivering up to 40 to 60 pounds per square inch, or 93 to 185 feet of pressure, at the sprinkler nozzle (depending upon the requirements of the sprinklers used).

Pump efficiency will vary from approximately 50% for a small self-priming pump to about 80% for a large straight centrifugal pump. Most wastewater pumps will probably have an efficiency in the range of 60 to 70%. Electric motor efficiency is normally taken to be 90%. Air-cooled gasoline engines have an efficiency of approximately 65%. Water-cooled gasoline engines are about 70% efficient, while diesel engines have an efficiency of about 75%.

The equation for computing motor or engine horsepower is:

$$\text{Horsepower (HP)} = \frac{\underset{\text{(gallons/minute)}}{\text{pump capacity}} \times \underset{\text{(feet)}}{\text{TDH}}}{3{,}960 \times \underset{\text{(decimal)}}{\text{pump efficiency}} \times \underset{\text{(decimal)}}{\text{motor/engine efficiency}}}$$

For more detailed information about irrigation pumps, see *Liquid Manure Application Systems Design Manual*, NRAES–89, which is listed in "Suggested Readings" on page 63.

Irrigation Pipe

Pipe for irrigation is usually aluminum or plastic (PVC). Aluminum pipe is used aboveground for portable irrigation systems, to get from a pump to a field edge, or to get from a hydrant to an irrigator or sprinkler. Aluminum pipe ranges in size from 2 to 8 inches in diameter and comes in 20- to 40-foot lengths. Aluminum is subject to corrosion and should be flushed out regularly with clean water. It is also easily damaged from handling and aboveground traffic.

Plastic pipe is usually less expensive than aluminum and is used in permanent installations. Exposure to ultraviolet sunlight rays makes plastic pipe brittle. Polyvinyl chloride (PVC) pipe is available in sizes ranging from 0.5 to 12 inches in diameter and comes in 20- and 40-foot lengths. PVC pipe is available in five class ratings: Class 100, Class 125, Class 160, Class 200, and

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Class 315, where the numbers denote the working pressure in pounds per square inch. The wall thickness of any class of pipe will increase as the pipe diameter increases, so that all sizes will have equivalent pressure ratings.

There are two schedules of pipe: Schedule 40 and Schedule 80. Schedule 40 PVC pipe can be compared to lightweight steel pipe, and Schedule 80 compares to regular-weight steel pipe. These pipes would normally be used under traffic lanes or where extra strength is required. The wall thickness of the schedule pipe will be fairly constant regardless of pipe diameter. Therefore, as the diameter increases, the pressure rating decreases.

PVC pipe is connected with either bell-and-gasket or solvent-weld fittings. All fittings are external to the pipe. Usually, pipes smaller than 2 inches in diameter are connected with solvent-weld fittings. Pipes 2 inches or larger in diameter may also use bell-and-gasket fittings. For all piping systems using any bell-and-gasket fittings, concrete thrust blocks are required at the end of a line of pipe and at changes in direction in the line. These thrust blocks prevent the pipe from pushing apart, usually because of water hammer or abrupt direction changes.

Irrigation Equipment

Sprinkler irrigation has been the most successful method used for wastewater application. Furrow, border, corrugation, flood, and gated pipe have all been used with limited success. The difficulty of getting even nutrient distribution in the field without excessive amounts of labor is a major drawback of these methods.

Sprinklers and spacings must be selected to avoid runoff for the particular soil type, topography, crop, application time, and wastewater characteristics. Sprinklers range in size from ⅛-inch-diameter nozzles to guns with nozzles up to 2 inches in diameter. Discharge volume is controlled by nozzle size, number of nozzles, and operating pressure. Liquid (excluding surface scum) from properly sized lagoons can be applied through ¼- to ⅜-inch nozzles. These nozzles typically operate at 30 to 60 pounds per square inch pressure. Single-nozzle, taper-bore sprinklers are recommended for all types of wastewater irrigation because of the reduced chance of plugging. Large nozzle sizes (¾ to 2 inches) should be used for irrigating the contents of lagoons or holding ponds with high concentrations of solids. Typical operating pressures range from 60 to 90 pounds per square inch at the sprinkler.

Sprinkler spacings are normally 60% of their wetted diameter. This is to allow overlap along the outer portions of the wetted circles, since the application rate decreases in these areas. The closer sprinklers with the same flow rate are spaced, the higher the application rate will be. Consequently, the farther apart they are, the poorer the uniformity of distribution and field coverage.

Hand-moved sprinklers use a mainline and one or more laterals of aluminum pipe sections. As the pump runs, a strip is sprinkled as long as the lateral and as wide as the coverage diameter of one individual sprinkler (figure 7-11). After that set is irrigated, the pump is shut off, the pipe is disassembled and moved to a new set, the pipe is reassembled, and the new set is irrigated. This system has low initial costs but high labor requirements. Moving portable pipe in a wastewater irrigation system is an unpleasant task.

Permanent solid-set systems (permanently installed throughout an entire field) are generally very expensive to install and usually are limited to small areas up to 25 acres. They do eliminate much of the labor, however, since all of the pipe is underground. A field has to be dedicated to receiving wastewater long-term, since the equipment cannot be moved. High-solids-content wastewaters should not be pumped through a system of this type, especially if small pipe sizes and sprinkler nozzles are used, because of the solids plugging potential.

Traveling guns are most often used for larger acreages and large volumes of wastewater. Travelers can be of two types. A

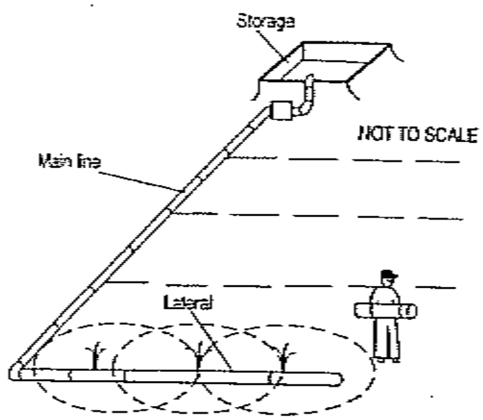

Figure 7-11. Hand-moved sprinkler system
Source: Natural Resources Conservation Service

cable-towed traveler consists of a single gun sprinkler mounted on a wheeled cart with a cable winch anchored to a stationary object at the end of the field. The cable winch is powered by a water turbine operated by the water pressure feeding the sprinkler, or a small internal combustion engine. The sprinkler is connected to 660 feet of collapsible hose, which is pulled along behind the cart as it is winched through the field. The other end of the hose is connected to a hydrant at field edge being supplied by a pump at the lagoon. A disadvantage of this traveler is that the entire length of hose must be unreeled and laid out before irrigation begins regardless of the field length. At the end of the irrigation event, the hose must be drained and rolled back up. More labor is required compared to alternative types of travelers. Also, the turbine drive easily clogs with solids.

Another type of traveler consists of up to 1,000 feet of hard polyethylene hose wound around a large reel 8 to 12 feet in diameter mounted on a wheeled chassis (figure 7-12). The unit is parked at the edge of the field and connected to a wastewater hydrant. A single gun sprinkler is mounted on a cart and attached to the end of the hard hose. The gun is pulled to the other end of the field, unwinding the hard hose from the reel. The reel then slowly winds the hose back up, pulling the sprinkler gun back toward it. The reel is powered either by a water turbine drive or an auxiliary engine, which eliminates the plug-

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ging problems associated with wastewater solids. The reel speed can be varied to get the desired application rate. This type of unit is more labor-free and can easily irrigate 10 or more acres before having to be moved to another travel lane. Also, it can easily accommodate uneven travel lengths. It is more expensive, however, and increases power requirements due to increased pipe friction losses.

Center-pivot systems, which move around in a circle like the spoke of a wheel and can cover up to 1,000 acres, offer almost complete automation (figure 7-13). Their disadvantages include relatively high cost, low pressure, small sprinklers, and maintenance problems. Good design may help offset some disadvantages.

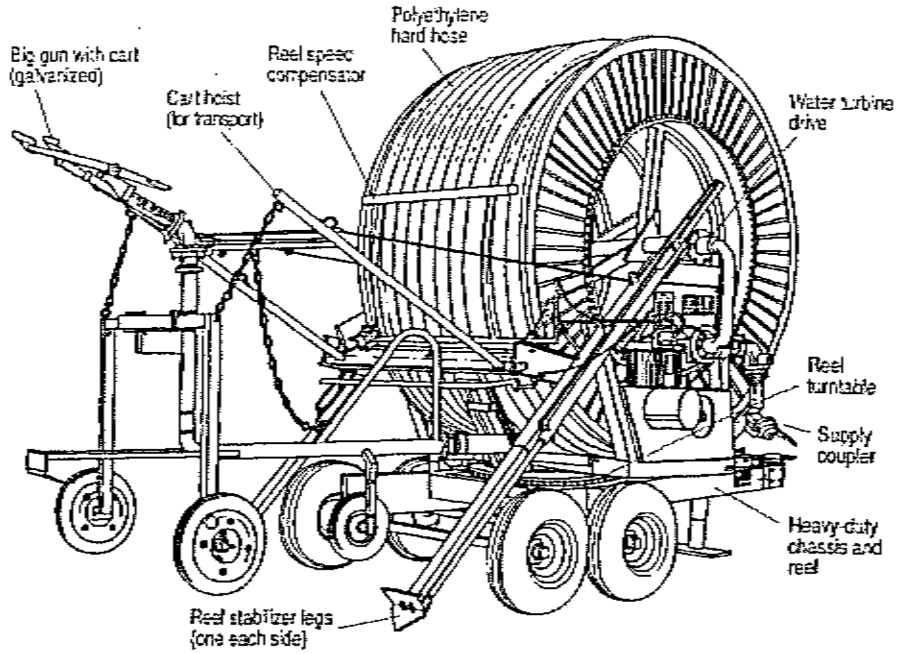

Figure 7-12. Hard-hose reel with traveling gun cart suspended (for travel)
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

Calibration of Irrigation Systems

Irrigation rates are usually defined by a combination of pumping or flow rate, sprinkler nozzle diameter and operating pressure, sprinkler wetted diameter, sprinkler spacing, and travel speed. Pumping rates are given by the manufacturers' data curves and depend on the motor size, amperage drawn or operating speed, suction lift, and operating pressure. The greater the amps or speed, the higher the flow rate. Higher suction lifts and/or operating pressures decrease the flow rate. Flow rates can be practically checked only using in-line flow meters, whose reliability in wastewater is questionable, or with external Doppler-type flow meters, which are expensive.

Rotary-impact sprinkler nozzle discharge rates depend on the nozzle diameter and nozzle operating pressure (which is different from pump pressure). Manufacturers' data give flow rates for different nozzle diameters and pressures. Nozzles can wear with age, particularly if the wastewater contains sand or grit, which results in higher flow rates or uneven distribution.

Application rates depend on the wetted diameter (area), nozzle type (taper-bore or ring), nozzle trajectory above ground, and sprinkler spacing or overlap. Taper-bore nozzles provide larger droplet sizes covering more area and result in lower application rates and less wind drift than ring nozzles. High-trajectory sprinklers cover less area, resulting in higher application rates and more wind drift than low-trajectory nozzles.

Uniformity of application depends on sprinkler spacing and wind velocity. Stationary sprinklers are usually spaced at no more than 60% of their wetted diameter. To measure the application rate and uniformity under stationary sprinklers, a number of containers or rain gauges can be equally spaced in two perpendicular transects under the full-circle sprinkler. The container spacing should be no more than 10% of the wetted diameter. After irrigating for a specific time period, measure the depth of liquid in the containers (in inches) and divide by the operating time (hours) to get the application rate and uniformity of application.

Traveling sprinklers have the added variable of forward travel speed affecting the application rate. Lane spacing for traveling sprinklers is normally 70 to 75% of sprinkler wetted diameter for uniform overlap. Travelers have adjustable sprinkler travel speeds for varying the application

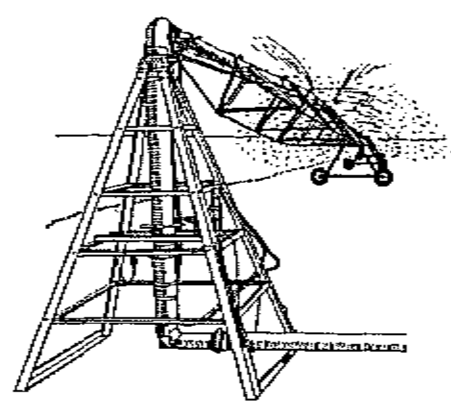

Figure 7-13. Pivot irrigation system with big gun sprinklers
Source: *Liquid Manure Application Systems Design Manual*, NRAES–89

rates that are charted on the machine by the manufacturer. Since the empty hose reels at the beginning of a sprinkler pull have a smaller diameter, the sprinkler travel speed at the beginning of the pull will be slower than it is near the end of the pull when the hose reel is full and has a larger diameter. To compensate for this difference, manufacturers place speed compensators on the hose-reel travelers to ensure the sprinkler travel is the same from beginning to end. This device should be a must for all traveling wastewater irrigators. A periodic check of the travel speed can be performed by painting a mark on the sprinkler hose near the sprinkler. Place two stakes 100 feet apart near the hose at the beginning of the pull and again near the end of the pull. Record the time it takes for the mark on the hose to travel between the stakes and compare this actual travel speed with that specified by the manufacturer.

Salt Formation on Wastewater Pumping Equipment

Widespread implementation of wastewater pumping technology has improved waste handling from layer production facilities through flushing of wastes from buildings. This reduces gases and odors and may improve bird performance, health, and in-house working environment. Implementation of this technology has also resulted in the buildup of a grayish-white crystalline salt on the internal pump and piping surfaces used for lagoon liquid pumping. This compound is predominantly magnesium ammonium phosphate, sometimes referred to as struvite. Deposits occur most frequently on metallic surfaces but also occur in varying degrees on plastics. Among metal components, steel, cast iron, bronze, and brass appear to be about equally susceptible.

Salt buildup is usually first detected in the internal pump components, gradually moving outward into discharge pipes. Deposition also occurs at pipe joints, elbows, valves, or imperfections, because grit and manure solids tend to lodge at these points, providing a base for the salt to grow. Predicting the occurrence of salt crystallization and deposition is difficult, since exact causes are not well defined.

Minimize salt problems by selecting high-quality, low-pressure, self-priming centrifugal or submersible pumps. Ground the pump housing to prevent an electrostatic charge from building up on the metallic parts. You may oversize the pump and piping system to obtain the needed delivery, but operate the pump on a timer and allow the system to drain between use; contact time between the pump and pipes and the wastewater can be greatly minimized in this manner. Be sure to avoid significant oversizing of pumps in relation to the piping network to minimize high pipe flow velocities and excessive pump cavity turbulence caused by restricting the discharge. Ensure that the suction line is large enough to prevent pump cavitation. (Rule of Thumb: The suction pipe diameter should be one standard size larger than the discharge pipe.) Locate the pump as close to the high water level of the lagoon as possible to minimize suction lift. Replace fine mesh suction intake strainers with wire screens or baskets that have 1-inch mesh or larger and a diameter at least five times the suction pipe diameter.

Use nonmetallic pipe and fittings. Consult pump experts to size pipe diameters so they are large enough to maintain flow velocities between 3 and 5 feet per second. The piping system from the wastewater source to the point of use should be a minimum of 1 inch in diameter, except at the immediate vicinity of the discharge point. Salt deposition problems are typically less in large lines than in smaller ones. Sharp pipe bends such as elbows and tees should be minimized by substituting flexible plastic pipe and long sweep elbows for direction changes.

The pump and piping system should have enough capacity to allow operation only one-half to two-thirds of the time. Piping systems not in continuous use should allow draining between pumping events.

Direct grounding of the pump housing discharges any static charges or stray voltage, which is believed to contribute to salt deposition. A metal rod should be driven 10 to 12 feet into moist soil near the lagoon edge. Cable connections at the ground rod and pump should be checked periodically for corrosion to ensure that the system maintains good electrical conductivity.

Salt deposition problems may be related to increasing concentration of compound materials in the lagoon systems. Primary lagoons should be properly sized with adequate treatment capacities. A new lagoon should be charged at least half full of water prior to startup, and the liquid level should be brought up to design levels as soon as possible. Rainfall in more humid regions during normal years dilutes lagoon liquid concentrations. Extended periods of hot, dry weather increase nutrient and salt levels and the rate of salt buildup in recycling and irrigation systems. During these dry periods, flushing with fresh water or irrigating a portion of the lagoon contents and replacing the liquid loss with fresh water may help.

Salts can be dissolved from internal pump and pipe surfaces with dilute acid treatments. Several dosings followed by flushing of the spent acid solutions will be needed for removal of heavy buildups. A more thorough but costly treatment can be obtained by installing an acid recirculation loop. A 150-gallon acid-resistant tank can serve as an acid recirculation reservoir. The tank should supply enough total solution to fill the pipe length to be cleaned, plus some reserve to keep the recirculation pump primed. To reduce tank size, line sections can be isolated with valves so that acid is circulated through only one section. The flush pump suction line is switched from the lagoon and connected to the bottom of the acid tank with a quick-connect coupling. A 1-inch line returns acid from the end of each treated pipe section to the tank.

Muriatic (hydrochloric) acid (30% technical grade), which can be purchased at most chemical supply houses or paint stores, should be diluted (1 gallon acid added to 9 gallons of water). **WARNING: Extreme caution must be exercised. Mixing acids with water can be very hazardous. Never add water to the concentrated acid. Always partially fill the tank with water, then add the acid to the water very slowly. Heat will be generated. Eye protection is advisable.**

This solution should be recirculated overnight for a heavy salt buildup. This dilution should not damage metal, although prolonged contact should be avoided. A heavy buildup may render the acid usable only one time; although it should be retained after the first use and reused to see how much strength remains. Spent acid may be dumped to the lagoon.

CHAPTER 8

Dead Bird Management

A by-product of even the most successful poultry production operations is dead birds. Despite improved health and production practices, intermittent mortality is to be expected in commercial flocks. Regardless of the cause of the mortality, proper disposal of carcasses is required to ensure biosecurity, protect the environment, and avoid offending others with nuisance conditions.

Two general categories of carcass disposal are: (1) normal mortality (typically about 0.1% per day, with fluctuation up to 0.25% not uncommon); and (2) disposal of large portions of the flock or a whole flock (usually associated with sacrifices due to contagious disease outbreak or death due to power outages or other catastrophes). Normal mortality is generally more easily handled because of the steady "flow" of material through the disposal system.

Methods for disposal of dead birds are burial, incineration, rendering, and composting. The method chosen must be compatible with the individual grower's situation and management capabilities and must comply with state laws. Fabricated pits for burial have been used in many areas, but questions have been raised about their impact on groundwater quality, and they have been prohibited in many states. Incineration is perhaps the most biosecure method of disposal, but it tends to cause odor and maintenance problems. In addition, it tends to be slow and expensive. For producers located close to a rendering plant or pickup route, this process can be an attractive and economical method for disposal of normal and catastrophic mortality. However, there are biosecurity risks associated with transporting carcasses to a rendering plant or with farm pickup systems. Also, some rendering plants may not be able to handle large quantities of carcasses from catastrophic events. Composting of dead birds is gaining popularity, but it requires investment in new facilities and has not received unconditional approval by regulatory authorities in all states.

Rendering Poultry Mortality Losses

Rendering is the process by which a waste or other product (carcasses) is placed under at least 40 pounds of steam pressure in a kettle or vat. The waste is thoroughly cooked for a sufficient time to destroy the product for human food purposes while precluding the spread of disease when it is consumed by animals or poultry.

The most obvious requirement for utilizing rendering as a carcass disposal option is close proximity to a rendering plant that accepts whole dead birds or that provides a truck route to pick up mortality from individual farms or from a convenient pickup station. The poultry industry as a whole may be unwilling to have rendering route trucks driven onto individual farms because of questions about biosecurity. An option is to provide central pickup stations where producers deliver their individual farm mortality, load their dead birds onto the renderer's truck or trailer, and then disinfect their vehicles prior to returning to their farms.

An approach that has been used in some areas has been the use of a household freezer (usually chest-type) or specially designed freezer units on the poultry farm to temporarily store normal mortality. Dead birds should be picked up daily from houses and placed in the freezer. Periodically, usually once or twice a week (depending on the age and size of the birds and rate of mortality), the grower must carry the frozen carcasses to the rendering plant or to a pickup station. Quality of carcasses is preserved by freezing, and nuisance potential is reduced while minimizing the expense of transporting dead birds to the rendering plant. At the plant, birds are unloaded for processing along with poultry plant processing wastes, other dead animals, and other protein and fat waste products. Biosecurity practices vary from plant to plant and from state to state. Generally, however, the industry encourages producers who haul to the rendering plant to disinfect their trucks and hauling containers as they leave the plant. Most producers are concerned about disease transfer potential and are willing to make use of washing and disinfection facilities if they are provided.

Processes have been developed to use biological fermentation or direct acidification of carcasses on the farm. These processes allow the grower to accumulate large quantities of mortalities on the farm without spoilage until such time as they can be transported in bulk to rendering plants or other facilities for recycling into foodstuffs or other value-added products. While not

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in widespread use, these methods may find more extensive use in the future.

The renderer, in order to produce a finished product of high quality, must have raw waste products that are fresh and of consistent quantity and quality. Dead birds generally do not meet this requirement, but acceptance of normal, small quantities of mortality are generally not a problem. However, when large quantities of dead birds must be processed, such as when whole house deaths occur from power outages or other catastrophes, plants must adjust to accept these carcasses. Some renderers are unable to process large quantities of these birds because of the reduction in quality of their end products. For example, if a plant has contracted to sell all of its product as pet food, the added likelihood of more visible feathers in the processed food will be unacceptable, and the renderer may not accept the dead birds.

Composting Routine Poultry Mortality Losses

Composting of poultry carcasses has become the method of choice for disposal of normal mortality losses on many poultry farms. Several different designs of composters are available, but they must all meet the following requirements:

- must be practically odorless;
- must operate at a temperature high enough to destroy pathogenic bacteria (150°F);
- must provide for complete decomposition of carcasses—only minimal amounts of feathers and bones remaining;
- must be adequately protected from flies so that maggots are not a problem; and
- must keep out other vermin and wild or domestic animals.

Composter design can vary considerably and still work well. One popular system includes several small primary bins approximately the same width of the loader bucket used to handle the bin contents. The bin depth is about 5 feet, due to the reach required to scoop the primary bin contents and drop them into a secondary bin, which is typically located behind the back wall of the primary bin. The layering arrangement for routine composting of normal mortalities in primary bins is shown in figure 8-1. Moving the primary bin contents and "cascading" the compost mixture into the secondary bin(s) provides aeration to rejuvenate the composting process and bring it to a stable conclusion. Of course, other composter designs can accomplish the same process. Experience indicates that certain features are common to all good composters:

- Roof: Some materials are composted outside. However, this is not recommended for dead bird composting. A roof ensures all-weather operation and helps control rain, snow, runoff, percolation, and leachate—all of which can be major concerns. Figure 8-2 shows a multi-compartmentalized two-bin design that includes a roof.
- Floor: A concrete floor is recommended to ensure all-weather opera-

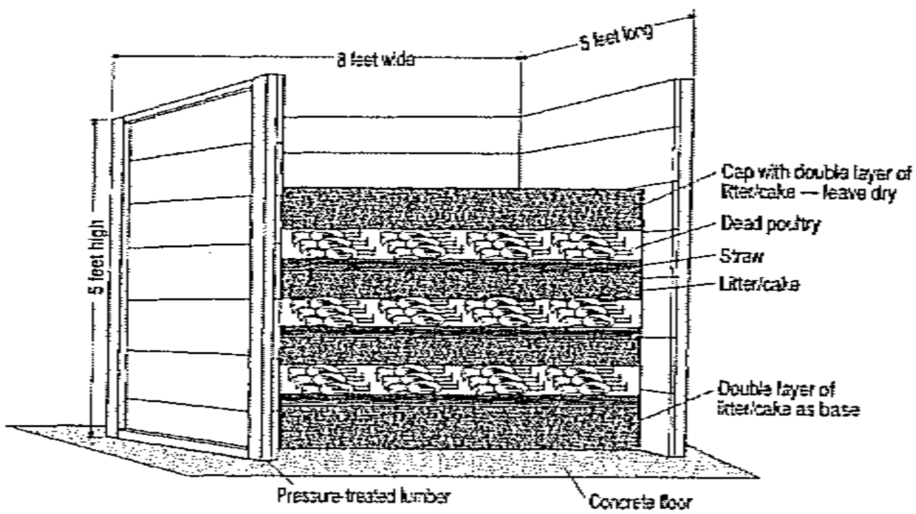

Figure 8-1. Layering arrangement for routine composting of normal mortalities in primary bins

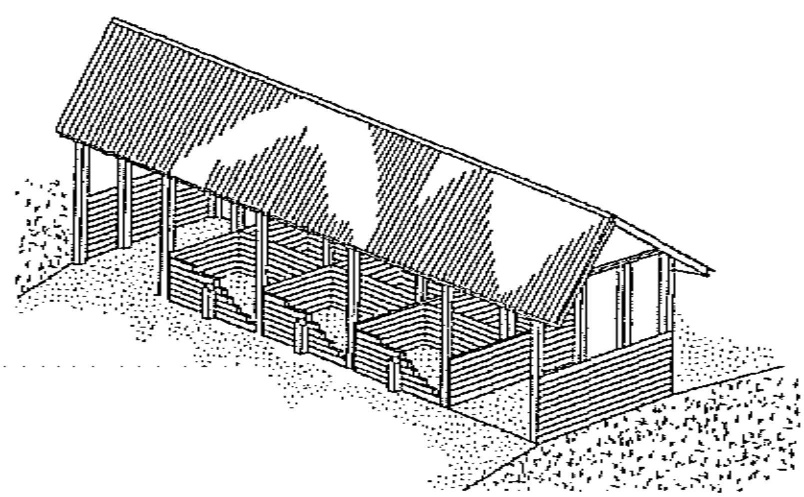

Figure 8-2. Roofed composting facility with two-bin, multi-compartmentalized design
Source: *Field Guide to On-Farm Composting*, NRAES-114

tion and to secure the composter against burrowing from rodents or other animals. An impervious floor also will help dispel questions about contamination of the groundwater and other surrounding areas. An optional concrete apron, sloped away from the primary bins, is recommended. This provides an all-weather surface for equipment and operation.

- Building materials: Specify preservative pressure-treated lumber or other rot-resistant materials that can resist the biological activity of composting. Use hot-dipped galvanized nails, which resist rusting, or other fasteners that are compatible with the materials used.
- Access to primary bins: A method is needed to enclose and confine the compost mixture but allow access with a bucket loader for efficient handling. One technique that works well is to construct channels on the sides of front bin posts using angle iron or wood cleats. Treated boards can then be slipped into the channels to form a front wall, or "gate," as layers are stacked in the bin. Conversely, the boards can be removed after the composting is completed to give access to the bin with a bucket loader.

Temperature is a good indicator of biological activity in the compost pile and is easily measured using a long-stemmed dial thermometer (see figure 4-6 on page 24) or an electronic probe thermometer. Moisture content, oxygen availability, and microbial activity all influence temperature. Two or three days after wastes are mixed and placed in piles, thermophilic microbes should begin to dominate. These organisms prefer a temperature of 100 to 150°F. As conditions in the pile change—for example, due to an unfavorable moisture content, change in the C:N ratio, or decreasing oxygen supply—the temperature may drop and the microbial population will shift back to a regime of lower-temperature microbes.

As long as the temperature is increasing, the pile is functioning well and should be left alone. As the temperature peaks and then begins to decrease, the pile should be turned to incorporate oxygen. After turning, the pile should respond to the mixing and incorporation of oxygen, and the temperature should again cycle upwards. Ideally, the turning process should be continued until the reheating response does not occur again; this indicates that the compost material is biologically stable.

If you are serious about using composting for dead bird disposal, be sure to seek more detailed information on dead poultry composting from your local Cooperative Extension office. Two publications listed in "Suggested Readings" on page 63, *On-Farm Composting Handbook* (NRAES–54) and *Field Guide to On-Farm Composting* (NRAES–114), contain more detailed information about composting systems and management.

Applying Composting Principles to Catastrophic Poultry Mortalities

Catastrophic mortalities are those caused by uncontrollable events, such as suffocation because of power outages, flooding, flock destruction because of disease, and hot weather. Composting of these losses must be dealt with in a different manner than normal composting because of the large initial volume. However, the principles are the same.

If a whole house is involved, the logical place to compost is in the house. This would be particularly true if a disease is involved. Most of the litter can be composted with the birds, thus killing disease organisms in the process. In-house composting will provide shelter in case of bad weather and enable better control of the process. The recipe for catastrophic poultry mortality composting is the same as for normal mortality described by Murphy and Carr (1991); Collins (1992); and Langston, VanDevender, and Boles (1998). The volumetric ratio is one bird:two litter:one straw. The basic difference is that a windrow formation for the catastrophic losses will be used instead of the typical on-farm poultry composter (figure 8-3). The windrow can be triangular or trapezoidal in shape. The base width can vary from 8 to 12 feet with a height of 4 to 6 feet. The windrow can be as long as necessary. Keep the birds at least 6 inches from the outside face of the windrow, and do not layer over two birds deep. As the windrow is formed, additional water may be required, because the litter may be dry. Internal windrow moisture should approach 50%. Turning of the windrow in seven to ten days will be necessary to add

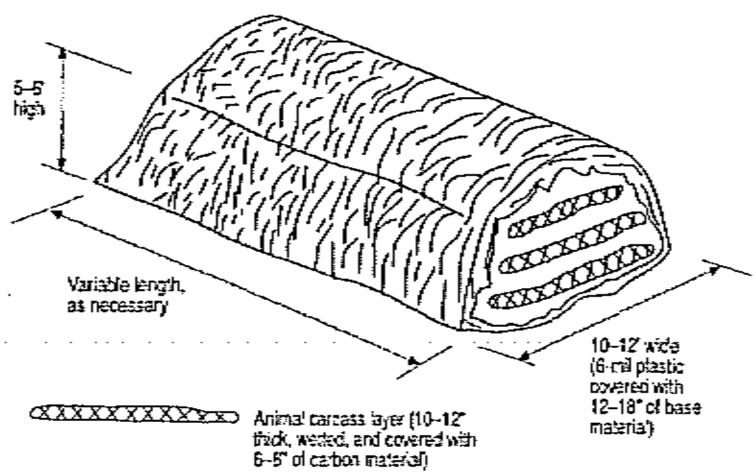

Figure 8-3. Windrow design used for composting catastrophic mortality
Source: *Field Guide to On-Farm Composting*, NRAES-114

additional oxygen to the process and to further disperse the carcass mass into the compost mixture.

If there is insufficient ceiling clearance to turn the windrow inside the house, you may have to move the compost mixture outside for the second-stage composting cycle. A layer of 6-mil polyethylene should be used under the compost windrow outside. To prevent damage to the polyethylene in the turning process, a layer of straw 12 to 18 inches deep should be used as a depth gauge. As the pile is reconstructed, be sure that any partially composted carcasses are covered with at least 6 inches of litter and that no bird tissue is left on the surface of the windrow.

If there is a partial house catastrophic loss, you may have to start the primary-stage composting cycle outside or in your manure storage shed if there is space available. As described above, provide the layer of 6-mil polyethylene covered with the straw layer depth gauge. Build the windrow layers with 12 inches of litter and then follow the layering process shown in figure 8-1 (page 56). If composting will be in a manure storage shed with a concrete floor, the protective "depth gauge" of straw will not be required. If composting will be done outside, be sure to select a site that is well-drained without the possibility of surface drainage running into or through the compost windrow or pile.

Safety in Composting

The composting of dead birds, when properly done, is an economical disposal method that is far gentler on the environment than incineration, single burial, or burial in disposal pits. Since the whole process takes place aboveground and in proximity of other animals, early concerns were expressed about the survival of pathogens. So early-on trials were made both on-site and in laboratory tests to duplicate actual, natural composting.

In early trials, the virus causing Infectious Bursal Disease (gumboro disease) was used because of its extreme hardiness. The virus was found to persist after seven days but was dead after fourteen days of composting. In another experiment, where both the Infectious Bursal Disease virus and the Newcastle Disease virus were used, it was found that, as in the first trial, the Infectious Bursal Disease viruses survived seven days but not fourteen days, while no trace of live Newcastle Disease virus could be found after seven days of composting.

Under laboratory conditions, other tests were conducted with ground beef inoculated with *Mycobacterium pseudotuberculosis*, the agent causing Johne's Disease in ruminants. No bacteria survived at 150°F. Also, ground beef was inoculated with *Salmonella dublin* for two trials; one at 150°F and the other at 130°F. At 150°F, all bacteria were killed within 6 hours. At 130°F, no live bacteria were found after 18 hours of composting.

Trials in Alabama showed that coliform bacteria are sometimes recovered during first-stage but not after second-stage composting. Recontamination of the compost by viruses is unlikely. Viruses need intact live cells to replicate, and as the composting progresses, the animal tissues assume the appearance of cooked meat. The cells die and undergo such change that even under microscopic examination, it would be difficult to identify the tissue. Recontamination of material after composting is caused by environmental bacteria carried by insects, rodents, and/or equipment.

In summary, it can be safely assumed that if composting is done properly and reaches the projected temperatures, pathogens present in carcasses prior to composting will be destroyed.

Incineration of Mortality

Incineration, or cremation, is a safe method of carcass disposal and may be an alternative to other methods of disposal. The major advantage of incineration is its security—it is biologically secure, and it will not create water pollution problems. Ash is easy to dispose of and does not attract rodents or pests.

On the other hand, incineration is often slow and costly—and likely to become more expensive as fuel costs rise. Incinerators must be properly sited, too, because unpleasant odors may accompany the process. Indeed, an air quality issue for poultry growers who choose this method of mortality management is the emission of odor and particulates (dust, ash, etc.) that may be generated during the process.

Nevertheless, incineration is considered very sanitary when properly applied. Homemade incinerators—that is, 55-gallon barrels or drums containing carcasses that have been drenched in a flammable liquid—are *not acceptable* and *do not* meet air quality standards.

Good Incinerator Design

Incinerator design and use are often regulated. Producers considering this method of poultry mortality management should consult with appropriate state environmental agencies before incorporating incineration into their mortality management plan. A variety of good commercial incinerators are available that will ensure a proper burn and air quality safeguards.

Incinerators should be sturdily built and able to accommodate normal daily mortalities. Those that have automatic controls are most convenient. The unit should be able to handle large loads and high temperatures, and the size of the incinerator should also be carefully estimated to avoid overloading the equipment. Other disposal methods should be included in a resource management plan to cover situations in which heavy, unexpected losses occur.

Incinerator Location

Additional considerations include the location and proper operation of the incinerator equipment. Nuisance complaints about incinerators are many. Where and how equipment is installed and operates will influence the frequency of these complaints. First, locate the unit downwind of the poultry house, residences, and neighbors' properties. Second, be sure that the discharge stack is far enough away from trees or structures to avoid fires. Incinerators burn at intensely high temperatures. Locating the incinerator in an area convenient to the poultry house will also contribute to better management.

Sheltering the incinerator from inclement weather will extend the life of the unit. For best results, place it on a concrete slab inside a roofed structure.

Incinerator Costs

At least two items must be considered in determining the cost of incineration as a disposal method for poultry mortalities:

- equipment purchase and maintenance, and
- the rate of burn and fuel costs.

Purchase costs will vary depending on the size and type of the incinerator. Discharge stacks and afterburner devices that recycle the fumes can help control odors and dust, but air pollution is difficult to avoid with incinerators. Expendable parts and grates will need to be replaced periodically—perhaps every 2 or 3 years—and the whole system may need replacement (or overhaul) every 5 to 7 years.

The rate of burn will likewise vary depending on the weight, moisture, and fat content of the carcasses and on the loading capacity of the unit (incinerators may have to be loaded several times to handle a day's mortalities). Some broiler producers have experienced an average burn rate of about 65 pounds an hour; they estimate that it costs about $3.50 (1990 estimates) to incinerate 100 pounds of mortalities. If fuel prices increase, so will the cost of each burn.

Incineration is an acceptable and safe method of poultry mortality management. It does not risk the spread of disease or water pollution; however, it is relatively costly. Not only are direct costs involved in the process, but the choice of incineration also means the loss of most nutrient value that the mortalities might have had if they were composted for land applications or other uses.

CHAPTER 9

Alternative Uses for Manure

Processed Fertilizer

Several companies are making organic fertilizer from broiler and turkey litter and layer manure in the United States. A combination of processes are being used: composting and drying with or without enhancement with organic and inorganic substances. Some companies are making pelletized finished products. Others are making a granular product that looks similar to crushed pellets.

Ruminant Feed

When processed by an acceptable method, poultry litter is an economical and safe source of protein, minerals, and energy for beef cattle. Processed litter makes a good protein supplement for both brood cows and growing calves. Litter also makes an economical substitute for hay, especially during drought years when hay supplies are short.

Broiler litter is the most desirable type of litter for cattle feeding because of its superior nutritional value. It should contain 20 to 30% moisture and crude protein. It should also be low in ash (soil) and should be free of hardware, glass, and other foreign materials. Processed turkey, broiler breeder, and hen litter have also been used successfully as feed, but they are less desirable feedstuffs than broiler litter. Details of feeding guidelines for poultry litter can be found in the references at the end of this publication (Gerkin, 1992; Carter and Poore, 1995; Poore et al, 1995; and Selders and Osborne, 1994).

Acceptable methods of processing litter for cattle feed include deep stacking, ensiling, dehydrating, and extrusion-pelleting. The most common method is deep stacking, the process of stockpiling litter for later use. Before litter is fed, it should be deep-stacked and caused to go through at least one extended heating period. After stacking, the litter undergoes a combined partial composting-ensiling process. Bacterial action causes the stack to heat to a temperature between 140°F and 160°F. This temperature is sufficient to kill pathogens such as *E. Coli* and *Salmonella* that may be present in raw litter.

The deep-stacked litter stabilizes following the initial heating, but it is not turned and allowed to reheat as is done when composting litter; thoroughly composting litter reduces the energy and protein availability in the material. Overheating (160°F or higher) may occasionally occur, and it will reduce feeding value by damaging both protein and carbohydrates. This problem can be controlled by packing the stack, covering it with plastic, or both.

After a minimum of three weeks of heating, the litter should be ready for use as a feed. Once the litter has undergone the heating process, it will retain its feeding value for a period of up to 5 years.

Deep-stack processing should result in a product that has a fine texture and an odor that is similar to caramelized chocolate. It should also be free of an ammonia smell, thereby increasing its palatability. Litter that has overheated will have a black color with a burnt odor. Litter that is gray-colored with a strong manure smell did not heat sufficiently for good processing.

The method used to store litter is important, because storage techniques often spell the difference between low- and high-quality feed. The options described in the earlier section on litter storage (beginning on page 20) can all be used to adequately protect litter that will be used for feed.

Key points for feeding broiler litter to ruminants include the following:

- Beef cow wintering rations offer good potential for feeding broiler litter. Typical mixtures of 80% broiler litter and 20% ground corn (for palatability) or other palatable concentrate ensure adequate consumption. A small amount of hay or other forage should also be fed for normal digestion and health.
- Feed pregnant cows 13 to 15 pounds of the litter mixture per head per day, along with 2.2 pounds of hay or equivalent forage. For cows nursing calves, increase the amount of the litter mixture to 18 to 20 pounds per head per day while continuing to feed 2 to 3 pounds of hay or other roughage.
- Winter calves on 50% broiler litter and 50% ground corn, along with hay fed free-choice. Feeding 7 pounds of the mixture per day, 400- to 500-pound calves should produce gains of a little

over 1 pound per day. The mixture could also be fed with as little as 5 to 10 pounds of silage or 2 to 3 pounds of hay per head per day. The amount of the mixture should be adjusted, depending on the amount of hay or silage fed.

- Broiler litter can be substituted for up to 20 to 25% of the dry matter in beef cattle finishing rations. It can be fed either as litter ensiled with corn silage or by mixing deep-stacked litter with corn silage or other ration ingredients at feeding. When fed with silage plus concentrates, such as ground corn, at 1% of body weight, 20% broiler litter in the ration on an "as-fed" basis will provide all the protein needed to balance the ration.

Generally, no deleterious effects have been observed from feeding properly processed poultry litter to cattle. Copper toxicity is a potential problem when litter is fed to sheep. Broiler litter should not be fed to dairy cows while they are lactating, and its use should be discontinued fifteen days prior to slaughter of cattle and sheep.

Mushroom Compost

The microbial mixture prepared as the nutrient substrate for growing *Agaricus* mushrooms often includes poultry litter and/or manure. Mushroom substrate has major components of straw, sometimes straw-bedded horse manure, hay, corn cobs, or other plant by-products. Poultry manure is used as a nitrogen source to balance the carbon-to-nitrogen ratio for effective compost activity. In southeastern Pennsylvania, mushroom farmers frequently use dried layer manure or selected sources of broiler litter.

The specific temperature sequence used to prepare substrate provides for the release or conversion of free ammonia. Ammonia must be cleared from the substrate prior to spawning (introduction of mushroom mycelium), because gaseous ammonia is toxic to mushrooms. Some broiler producers use ammonia suppressant materials in their houses. These materials have been found to hold ammonia through the composting period used to prepare substrate. Later, ammonia gas is released during the growth of the mushrooms, causing crop damage. Therefore, broiler litter that contains ammonia suppressant materials is unacceptable for mushroom substrate preparation. Mushroom farmers have learned that it is essential to test new sources of poultry manure prior to making a purchase commitment.

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SUGGESTED READINGS

The following publications may be of interest to readers of the *Poultry Waste Management Handbook*. All are available from NRAES. Before ordering, contact NRAES for current prices and shipping and handling charges. Currently, NRAES has published more than 95 publications and distributes a total of more than 160 publications; contact NRAES for a free catalog.

NRAES is an interdisciplinary, issues-oriented program focused on delivering educational materials in support of cooperative extension. Read more about NRAES on the inside back cover of this book.

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Animal Agriculture and the Environment: Nutrients, Pathogens, and Community Relations

NRAES–96 • 386 pages • 1996

This proceedings includes 33 papers on the following topics: the fate of pathogens and nutrients, protecting the environment, land application, nutrient management plans, odor management, feeding management to reduce nutrients in manure, considerations in public policy, and cost to the farmer. The proceedings will be of interest to producers and their advisors; community officials and their consultants; regulatory agencies; educators; consultants; rural landowners; soil and water conservation district staff; government staff; and watershed managers.

Circular Concrete Manure Tanks

TR–9 • 23 pages • Revised, 1998

This resource from the MidWest Plan Service is for designers who understand reinforced concrete design, applicable codes, and soil properties. The design featured in the publication is for tanks with a hinged base and free top. This version of TR–9 is based on ACI–318 (Building Code Requirements for Structural Concrete) and differs significantly from earlier versions. It contains tables for general design data, tank capacities, and placement of reinforcing steel.

Concrete Manure Storages Handbook

MWPS–36 • 72 pages • 1994

Now the science and art of designing concrete storages are combined in one book! This reference book provides design and construction procedures for rectangular and circular storages based on current codes, standards, specifications, and engineering practices. The handbook is intended for engineers, designers, and builders who are familiar with material and functional design requirements, but it can also be useful to owners and users of the facilities. Natural Resources Conservation Service personnel will find this book a valuable resource.

Earthen Manure Storage Design Considerations

NRAES–109 • 100 pages • 1999

This book was written to meet the needs of producers, engineers, and design professionals who need information about designing, constructing, and managing earthen storages. It covers environmental policies; design standards and planning documents; manure characteristics; storage planning; storage design; construction; management; and liability. A lengthy appendix provides guidelines and calculations for soil liners.

Farm and Home Concrete Handbook

MWPS–35 • 41 pages • 1989

There are many uses for concrete around farms and homes, including walls, floors, drives, and other masonry construction. This compilation is a current reference for concrete users. Learn how to select a concrete mix and order ready-mix concrete. Details include forming, reinforcing, placing, finishing, and curing concrete. Selection and design recommendations for numerous practical applications are included. A major section covers the basics and preparations, weather precautions, and slip-resistant surfaces.

Fertilizer and Manure Application Equipment

NRAES–57 • 22 pages • 1994

This publication, written for small farms, discusses types of fertilizer and manure nutrient values and provides guidance on equipment selection. Procedures for calibrating fertilizer and manure application equipment are reviewed. The publication includes over 30 illustrations, six tables, a plan for a fertilizer storage shed, and a glossary.

Field Guide to On-Farm Composting

NRAES–114 • 128 pages • 1999

This book was developed to assist in day-to-day compost system management. Topics discussed in the book include: operations and equipment; raw materials and recipe making; process control and evaluation; site considerations, environmental management, and safety; composting livestock and poultry mortalities; and compost utilization on the farm. Highlights of the guide include an equipment identification table, diagrams showing windrow formation and shapes, examples and equations for recipe making and compost use estimation, a troubleshooting guide, and 24 full-color photos.

Liquid Manure Application Systems Design Manual

NRAES–89 • 168 pages • 1998

This up-to-date manual covers the following topics: characteristics and testing of liquid manure; evaluating sites; liquid manure from the barn to the field; field application; management; and applying the design procedure. Twenty tables and 69 illustrations are included.

Livestock Waste Facilities Handbook

MWPS–18 • 112 pages • 1985

Recommendations, federal regulations, and design procedures for almost all livestock manure handling and management alternatives are discussed in this book, including scrape systems, gravity drain gutters, gravity flow channels, infiltration areas, and waste transfer.

Nutrient Management: Crop Production and Water Quality

NRAES–101 • 44 pages • 1997

This full-color publication is divided into two sections: Basic Principles and Field Management. Basic Principles focuses on nutrient pathways and their behavior. Field Management centers on management guidelines that promote efficient distribution of nutrients to reduce fertilizer costs and the potential for loss. Two workbooks supplement this book (see below); they are sold separately.

- **Nutrient Management Workbook**

  NRAES–102 • 17 pages • 1997

  This workbook, a companion to *Nutrient Management: Crop Production and Water Quality* (NRAES–101), is used to record pertinent information and assist with calculations used in developing a nutrient management plan.

- **Estimating a Mass Nutrient Balance**

  NRAES–103 • 8 pages • 1997

  This workbook, a companion to *Nutrient Management: Crop Production and Water Quality* (NRAES–101), will help improve understanding of nutrient movement onto, within, and away from the farm.

Nutrient Management Software

NRAES–100 • 60 pages • 1996

This proceedings is from the Nutrient Management Software Workshop held in December 1996. Six papers are included: Comparison of Decision Support Systems That Calculate Manure Application Rates, Penn State Farm Nutrient Management Program, The "Nutrient Management Planner" and Farm Works Software, Cornell Nutrient Management Planning System, Cornell Net Carbohydrate and Protein System for Accurately Meeting Requirements of Cattle, and Purchasing a Computer for the Farm Business. Software is not included, but ordering information is given with each paper.

On-Farm Composting Handbook

NRAES–54 • 186 pages • 1992

This handbook contains everything you ever wanted to know about composting on the farm — why to compost (the benefits and drawbacks), what to compost (raw materials), how to compost (the methods), and what to do if something goes wrong (management). The ten chapters also discuss site and environmental considerations, using compost, and marketing compost. Highlighting the text are 55 figures, 32 tables, and sample calculations for determining a recipe and sizing a compost pad.

On-Farm Large-Scale Chicken Carcass Composting

NRAES–110 • 10-minute video • 1997

This VHS video offers producers a working knowledge of composting as a cost-effective and environmentally safe method for large-scale carcass disposal. It provides a step-by-step demonstration of windrow construction using various carbon sources. The video will be a helpful resource for producers, integrators, educators, and government agency personnel.

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About NRAES

NRAES, the Natural Resource, Agriculture, and Engineering Service (formerly the Northeast Regional Agricultural Engineering Service), is an interdisciplinary, issues-oriented program focused on delivering educational materials and training opportunities in support of cooperative extension. The mission of NRAES is to assist faculty and staff at member land grant universities in increasing the availability of research- and experience-based knowledge to improve the competitiveness and sustainability of agriculture and natural resources enterprises, increase understanding of processes that safeguard the food supply, and promote environmental protection and enhancement. All NRAES activities are guided by faculty from member land grant universities (see the map below for a list of cooperating members).

NRAES began in 1974 through an agreement among the cooperative extension programs in the Northeast. In 1998, Virginia Polytechnic Institute and State University became an NRAES member university. The program is guided by the NRAES Committee, which consists of a representative from each member university, the NRAES director, and an administrative liaison appointed by the Northeast Cooperative Extension Directors Committee. NRAES is housed in the Department of Agricultural and Biological Engineering at Cornell University. Office hours are Monday through Thursday, 8:30 A.M. to 5:00 P.M., and Friday, 8:30 A.M. to 2:30 P.M., eastern time.

Currently, NRAES has published more than 95 publications and distributes a total of more than 160 publications on the following topics: general agriculture, aquaculture, agrichemical handling, IPM, horticulture, greenhouses, building construction, livestock and poultry, dairy, waste management, composting, farm management, farm safety, forestry and wildlife, and home. Please contact us for a free publications catalog.

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